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John P. Fitzpatrick,
Director
**INFORMATION SECURITY
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October 14, 2015

Please be advised that the Interagency Security Classification Appeals Panel (ISCAP) has concluded its consideration of the mandatory declassification review appeal filed by you and that the 60-day period during which an agency head may appeal an ISCAP decision to the President has expired. Enclosed are copies of the documents and a chart that outlines the ISCAP decisions. With the exception of any information that is otherwise authorized and warranted for withholding under applicable law, we are releasing all information declassified by the ISCAP to you. If you have questions about this appeal, please contact Neena Sachdeva or William C. Carpenter at (202) 357-5250.

Sincerely,


JOHN P. FITZPATRICK
Executive Secretary

Enclosures

cc: Dr. David Sherman [Letter with Chart and Documents]
Associate Director for Policy and Records
National Security Agency

ISCAP DECISION ON MANDATORY DECLASSIFICATION REVIEW APPEAL

IDENTIFYING NUMBERS	DESCRIPTION OF DOCUMENT	ACTION
<p>Document No. 1 ISCAP No. 2009-049 NSA Case no. 54498, Appeal no. 3389</p>	<p>A History of U.S. Communications Security, Volume I July 1973 92 pages Secret</p>	<p>DECLASSIFIED SOME REMAINING PORTIONS AND AFFIRMED THE CLASSIFICATION OF OTHER REMAINING PORTIONS</p> <p>E.O. 13526, §§ 3.3(b)(1) and 3.3(b)(3), as 25X1 and 25X3</p> <p>Some information remains withheld by the National Security Agency under the statutory authority of the National Security Act of 1959, 50 U.S.C. § 3605 (Public Law 86-36)</p>
<p>Document No. 2 ISCAP No. 2009-049 NSA Case no. 54498, Appeal no. 3389</p>	<p>A History of U.S. Communications Security, Volume II July 1981 62 pages Secret</p>	<p>DECLASSIFIED SOME REMAINING PORTIONS AND AFFIRMED THE CLASSIFICATION OF OTHER REMAINING PORTIONS</p> <p>E.O. 13526, § 3.3(b)(3), as 25X3</p> <p>Some information remains withheld by the National Security Agency under the statutory authority of the National Security Act of 1959, 50 U.S.C. § 3605 (Public Law 86-36)</p>

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A HISTORY OF U.S. COMMUNICATIONS SECURITY (U)
(The David G. Boak Lectures)

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ISCAP APPEAL NO. 2009-049, document no. 1
DECLASSIFICATION DATE: October 14, 2015

INTRODUCTION

This publication consists of a series of lectures prepared and given to interns and other employees by Mr. David G. Boak in 1966. Mr. Boak is uniquely qualified to discuss the history of U.S. COMSEC because he has participated significantly in most aspects of its modern development over the past twenty years.

The purpose of these lectures was to present in an informal yet informative manner the fundamental concepts of Communications Security and to provide an insight into the strengths and weaknesses of selected manual systems, electro-mechanical and electronic crypto-equipments.

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FIRST LECTURE: The Need for Communications Security

I will spend most of this first period belaboring some seemingly obvious points on the need for communications security; why we're in this business, and what our objectives really are. It *seems* obvious that we need to protect our communications because they consistently reveal our strengths, weaknesses, disposition, plans, and intentions and if the opposition intercepts them he can exploit that information by attacking our weak points, avoiding our strengths, countering our plans, and frustrating our intentions. . . something he can only do if he has advance knowledge of our situation. But there's more to it than that.

First, you'll note I said the opposition can do these things *if* he can intercept our communications. Let me first give you some facts about that supposition. You've all seen the security caveats asserting that "the enemy is listening", "the walls have ears", and the like. One of my irreverent friends, knowing where I work, insists on referring to me as "an electronic spy", and popular paperback literature is full of lurid stories about code-breakers and thieves in the night careening to Budapest on the Orient Express with stolen ciphers tattooed somewhere unmentionable. What is the actual situation? We believe that the Soviet Signal Intelligence effort is greater in sheer manpower than the combined effort of the United States and the United Kingdom; a far larger portion of their national income is invested in signals collection than we invest in ours; their collection facilities include large land based sites, mobile platforms (air and sea), and satellite surveillance; and that they have an extensive covert collection operation. All in all, a truly formidable opponent. So the first "if" underlying our argument for the need for COMSEC (Communications Security) is more than a postulate—a deliberate, large, competent force has been identified whose mission is the exploitation of U.S. communications through their interception and analysis.

It is important to understand at the outset why the Soviet Union (as well as all other major countries) is willing to make an investment of this kind. Because, of course, they find it worthwhile. Sometimes, in the security business, you feel like a jackass having run around clutching defense secrets to your bosom only to find a detailed expose in *Missiles and Rockets* or the *Washington Post* or find it to be the subject of open conversations at a cocktail party or a coffee bar. There are, in fact, so many things that we cannot hide in an open society—at least in peace time—that you will sometimes encounter quite serious and thoughtful skepticism on the value or practicability of trying to hide anything . . . particularly if the techniques you apply to hide information—like cryptography—entail money, loss of time, and constraints on action.

What then, is unique about communications intelligence? What does it provide that our mountains of literature and news do not similarly reveal? How can it match the output of a bevy of professional spies or in-place defectors buying or stealing actual documents, blueprints, plans? ("In-place defector"—a guy with a *bona fide* job in some place like the Department of Defense, the Department of State, this Agency, or in the contractual world who feeds intelligence to a foreign power.) It turns out that there *is* something special about communications intelligence, and it provides the justification for our own large expenditures as well as those of other countries: in a nutshell, its special value lies in the fact that this kind of intelligence is generally accurate, reliable, *authentic*, continuous, and most important of all, *timely*. The more deeply you become familiar with classified governmental operations, the more aware you will become of the superficiality and inaccuracy that is liable to characterize speculative journalism. After all, if we've done our job, we have reduced them to speculation—to the seizing of and elaboration on rumors, and to drawing conclusions based on very few hard facts. This is by no means intended as an indictment of the fourth estate—it is merely illustrative of why Soviet intelligence would rather have the contents of a message signed by a government official on a given subject or activity than a controlled news release or journalistic guess on the same subject. Similarly, the outputs of agents are liable to be fragmentary, sporadic, and *slow*; and there are risks entailed in the transmission of intelligence so acquired. [Conventional SIGINT (Signals Intelligence) activity, of course, entails no risk whatever.]

Let me track back again: I have said that there is a large and profitable intercept activity directed against us. This does not mean, however, that the Soviets or anybody else can intercept *all* our communications . . . that is, all of them at once; nor does it necessarily follow that all of them are *worth* intercepting. (The Army has a teletypewriter link to Arlington Cemetery through which they coordinate funeral arrangements and the like. Clearly a very low priority in our master plans for securing communications.) It does mean that this hostile SIGINT activity has to be selective, pick the communications entities carrying intelligence of most value or—and it's not necessarily the same thing—pick the targets most swiftly exploitable. Conversely, we in the COMSEC business are faced with the problem not simply of securing communications, but with the much more difficult problem of deciding which communications to secure, in what time frame, and with what degree of security. Our COMSEC resources are far from infinite; not only are there constraints on the money, people, and equipment we can apply but also—as you will see later on—there are some important limitations on our technology. We don't have that *secure* two-way wrist radio, for example.

In talking of our objectives, we can postulate an *ideal*—total security for all official U.S. Government communications; but given the limitations I have mentioned, our more realistic objectives are to develop and apply our COMSEC resources in such a way as to assure that we provide for our customers a *net advantage* vis-a-vis their opposite numbers. This means that we have to devise systems for particular applications that the opposition will find not necessarily *unbreakable* but too costly to attack because the attack will consume too much of his resources and *too much time*. Here, we have enormous variation—most of our big, modern electronic cryptosystems are designed to resist a full scale "maximum effort" analysis for many, many years; we are willing to invest a big expensive hunk of complicated hardware to assure such resistance when the underlying communications are of high intelligence value. At the other end of the spectrum we may be willing to supply a mere slip of paper designed only to provide security to a tactical communication for a few minutes or hours because the communication has no value beyond that time . . . an artillery spotter names a target; once the shell lands, hopefully on the coordinates specified, he couldn't care less about the resistance to cryptanalysis of the coded transmission he used to call for that strike.

Now, if the opposition brought to bear the full weight of their analytic resources they may be able to solve that code, predict that target, and warn the troops in question. But can they afford it? Collectively, the National Security Agency attempts to provide the commander with intelligence about the opposition (through SIGINT) while protecting his own communications against comparable exploitation—and thus provide the net advantage I spoke of. I'll state our practical objectives in COMSEC once more: not absolute security for all communications because this is too expensive and in some instances, may result in a net disadvantage; but sufficient security for each type of communications to make its exploitation uneconomical to the opposition and to make the recovery of intelligence cost more than its worth to him. Don't forget for a moment that some TOP SECRET messages may have close to infinite worth, though; and for these, we provide systems with resistance that you can talk of in terms of centuries of time and galaxies of energy to effect solution.

The reason I have spent this time on these general notions is the hope of providing you a perspective on the nature of the business we're in and some insights on why we make the kinds of choices we do among the many systems and techniques I'll be talking to you about during the rest of the week. I happened to start out in this business as a cryptanalyst and a designer of specialized manual systems not long after World War II. It seemed to me in those days that the job was a simplistic one—purely a matter of examining existing or proposed systems and, if you found anything wrong, fix it or throw the blighter out—period. In this enlightened spirit, I devised many a gloriously impractical system and was confused and dismayed when these magnificent products were sometimes rejected in favor of some clearly inferior—that is, *less secure* system merely because the alternative was simpler, or faster, or cheaper; or merely because it would *work*.

Those of you who are cryptanalysts will find yourselves in an environment that is necessarily cautious, conservative, and with security *per se* a truly paramount consideration. This, I assert, is *healthy* because you, a mere handful, are tasked with outthinking an opposing analytic force of rhaps 100 times your number who are just as dedicated to finding flaws in these systems as you

must be to assuring none slipped by. But do not lose sight of the real world where your ultimate product must be used, and beware of security features so intricate, elaborate, complex, difficult, and expensive that our customers throw up their hands and keep on communicating in the clear—you have to judge not only the abstract probabilities of success of a given attack, but the likelihood that the opposition will be willing to commit his finite resources to it.

I hope you non-cryptanalysts smiling in our midst will recognize that we're playing with a two-edged sword—you are or ought to be in an environment where there is an enthusiasm for introducing to the field as many cryptosystems as possible at the least cost and with the fewest security constraints inhibiting their universal application. But don't kid yourselves: against the allegation that the COMSEC people of the National Security Agency—we're the villains—are quote pricing security out of the market unquote—is the fact that there is this monolithic opposing force that we can best delight by introducing systems which are not quite or not nearly as good as we think they are.

From this, we can conclude that, to carry out our job we have to do two things: first we have to provide systems which are cryptographically sound; and second, we have to insure that these systems can and will be used for the purpose intended.

If we fail in the first instance, we will have failed those customers who rely on our security judgments and put them in a disadvantageous position with respect to their opposition. But if we fail to get the systems used—no matter *how* secure they are—we are protecting nothing but our professional reputation.

Now that the general remarks about why we're in this business and what our objectives are are out of the way, we can turn to the meat of this course—my purpose, as much as anything, is to expose you to some concepts and teach you a new language, the vocabulary of the peculiar business you're in. To this end I will try to fix in your minds a number of rather basic notions or approaches that are applied in cryptography as well as a number of specific techniques as they have evolved over the past two decades.

There's a fair amount of literature—like the Friedman lectures—which is worth your time and which will trace the art of cryptography or ciphering back to Caesar or therabouts. I'll skip the first couple of millennia and such schemes as shaving a slave's head, writing a message on his shining pate, letting the hair grow back and dispatching him to Thermopylae or where have you. I'll also skip quite modern techniques of *secret writing*—secret inks, microphotography, and open letters with hidden meanings (called "innocent text" systems)—merely because their use is quantitatively negligible in the U.S. COMSEC scheme of things, and this Agency has practically nothing to do with them. What we will be addressing are the basic techniques and systems widely used in the protection of U.S. communications and which we are charged to evaluate, produce, or support.

All of our systems have one obvious objective: to provide a means for converting intelligible information into something unintelligible to an unauthorized recipient. We have discovered very few basic ways to do this efficiently. Some of the best ways of doing it have a fatal flaw; that is, that while it may be impossible for the hostile cryptanalyst to recover the underlying message because of the processing given it, neither can the intended recipient recover it because the process used could not be duplicated! On occasion there has been considerable wry amusement and chagrin on the part of some real professionals who have invented sophisticated encryption schemes only to find they were irreversible—with the result that not only the cryptanalyst was frustrated in recovering the plain text, so was the addressee. The inventor of a cryptosystem must not only find a means for rendering information unintelligible, he must use a process which is logical and reproducible at the receiving end. All of you know already that we use things called "keys" which absolutely determine the specific encryption process. It follows from what I have just said that we *always* produce at least two of them, one for the sender, one for the recipient. Through its application, and only through its application, the recipient is able to reverse, unscramble, or otherwise undo the encryption process.

The techniques that we have found useful so far amount to only two: first *substitution* of something meaningless for our meaningful text (our plain language); and second; *transposition*—keeping our original meaningful text, but jumbling the *positions* of our words or letters or digits so they no

longer make sense. This latter technique is so fraught with security difficulties—it's nothing but fancy anagramming—that for all practical purposes you can toss it out of your lexicon of modern U.S. cryptography. To get well ahead of our chronology of U.S. systems, the last transposition system we sponsored was called ALLEGRO and it collapsed utterly as soon as the analysts had a chance to attack a reasonable batch of operational traffic committed to it.

We are left with one very large family of systems in which the basic technique involves the substitution of one value for another. These range from systems whose security stems from a few letters, words, or digits memorized in somebody's head, through a variety of printed materials that permit encryption by use of paper and pencil, to the fancy electronic computer-like gadgets about which you have by now probably heard most. The first category of these systems we're going to talk about is manual systems and the first of these is codes. Professional cryptographers have been talking about codes, using them, attacking them, and solving them for many years. The traditional definition of them is: Code: "A substitution cryptosystem in which the plaintext elements are primarily words, phrases, or sentences, and the code equivalents (called "code groups") typically consist of letters or digits (or both) in otherwise meaningless combinations of identical length."—JUNE 71—*Basic Cryptologic Glossary.*

This definition provides a convenient way for differentiating a "code" from any other substitution system—all the other systems, which we call "ciphers", have a fixed relationship between the cipher value and its underlying meaning—each plaintext letter is always represented by one or two or some other specific number of cipher characters. Incidentally, we use "character" as a generic term to cover numbers or letters or digits or combinations of them. Let's look at a couple of codes:

1. The simplest kind, called a "one-part code", simply lists the plaintext meanings alphabetically (so that you can find them quickly) and some corresponding code groups (usually alphabetized also):

BRIGADE	ABT
COORDINATE(S)	AXQ
DIRECT ARTILLERY FIRE AT_____	CDL
ENGAGE ENEMY AT	GGP
-----	HLD
-----	JMB

There will usually be some numbers and perhaps an alphabet in such a code so that you can specify time and map coordinates and quantities and the like, and so that you can spell out words, especially place names, that could not be anticipated when the code was printed. Such a code has lots of appeal at very low echelons where only a very few stereotyped words, phrases, or directions are necessary to accomplish the mission. They are popular because they are simple, easy to use, and relatively fast. The security of such systems, however, is very, very low—after a handful of messages have been sent, the analyst can reconstruct the probable exact meanings of most of the code groups. We therefore take a dim view of them, and sanction their use only for very limited applications.

2. The kind of code we do use in very large quantities is more complicated, larger, and more secure. It is called a "two-part code": it is printed in two sections, one for encoding and the other for decoding:

ENCODE		DECODE	
BRIGADE	CDL	ABT	
COORDINATE(S)	AXQ	AXQ	COORDINATE(S)
DIRECT ARTILLERY FIRE AT_____	JMB	CDL	BRIGADE
ENGAGE ENEMY AT	GGP	GGP	ENGAGE ENEMY AT
-----	HLD	HLD	
-----	ABT	JMB	DIRECT ARTILLERY FIRE AT_____

The main thing that has been done here is to break up the alphabetical relationship between the plaintext meanings and the sequence of code groups associated with them—that is, the code groups are assigned in a truly random fashion, not in an orderly one. This complicates the cryptanalyst's job; but he can still get into the system rather quickly when the code is used repeatedly. As a result, a number of tricks are used to refine these codes and limit their vulnerability. The first trick is to provide more than one code group to represent the more commonly used words and phrases in the code vocabulary—we call these extra groups "variants" and in the larger codes in use today it is not uncommon to have as many as a half-dozen of these variants assigned to each of the high frequency (i.e., commonly used) plaintext values. Here's an excerpt from a code actually in use today showing some variants:

EXCERPTS FROM KAC-13/TSEC VOCABULARY

- XXX) RUNNING RABBITS (PULSED INTELLIGENCE)
- XXX) SAGE
- XXX)
- XXX) SCOPE JAMMED ON SECTOR...FROM....
- XXX) DEGREES TO...DEGREES.
- XXX)
- XXX) SCOPE SATURATED (JAMMING COVERS
- XXX) ENTIRE SCOPE)
- XXX)
- XXX) SEARCH RADAR
- XXX)
- XXX)
- XXX)
- XXX) SECRET

You probably know that "monoalphabetic substitution systems" were simple systems in which the same plaintext value was always represented by the same cipher or code value—repeats in the plain text would show up as repeated patterns in the cipher text, so lovely words like "RECONNAISSANCE" convert to, say,

RECONN AISSA NCE . . . duck soup! it says here.
SDEGBB XMLX BED

Well, with an ordinary code, that's exactly the problem. It is essentially a monoalphabetic system with a few variants thrown in, but with most repeated things in the transmitted code showing up as repeated items. This means, where we have to use codes (and later on, I'll show you why we have to in *huge* quantities), we have to do some things more fundamental than throwing in a few stumbling blocks like variants for the cryptanalyst. There are two techniques which are basic to our business and which we apply not only to codes but to almost all our keying materials. These are crucial to the secure management of our systems. These techniques are called *supersession* and *compartmentation*. They provide us a means for limiting the volume of traffic that will be encrypted in any given key or code; the effect of this limitation is to reduce the likelihood of successful cryptanalysis or of *physical loss* of that material; and further to reduce the scope of any loss that does occur.

SUPERSESSION is simply the replacement of a code or other keying material from time to time with new material. Most keys and codes are replaced each 24 hours; a few codes are replaced as frequently as each six hours; a few others remain effective for three days or more. We have these differing supersession rates because of the different ways in which the materials may be used. Holders of some systems may send only one message a day—everything else being equal, his system will have much greater resistance to cryptanalysis than that of a heavy volume user and his system will not

quire replacement as often. The regular replacement rate of material each six hours or 24 hours or three days or what have you is called the "normal supersession rate" of the material in question. "Emergency supersession" is the term used when material is replaced prematurely because it may have been physically lost.

Once again, the purpose of periodic supersession of keying material and codes is to limit the amount of traffic encrypted in any one system and thus to reduce the likelihood of successful cryptanalysis or of physical loss; and to limit the effect of loss when it does occur. The resistance to cryptanalysis is effected by reducing the amount of material the cryptanalyst has to work on and by reducing the *time* he has available to him to get at *current* traffic.

COMPARTMENTATION is another means for achieving control over the amount of classified information entrusted to a specific cryptosystem. Rather than being geared to time, as in the case of supersession, it is geared to communications entities, with only those units that have to intercommunicate holding copies of any particular key or code. These communications entities in turn tend to be grouped by geography, service, and particular operational mission or specialty. Thus, the Army artillery unit based in the Pacific area would not be issued the same code being used by a similar unit in Europe—the vocabularies and procedures might be identical, but each would have unique code values so that loss of a code in the Pacific area would have no effect on the security of messages being sent in the Seventh Army in Europe, and vice versa. Of course some systems, particularly some machine systems, are designed specifically for intercommunication between two and only two holders—between point A and point B, and that's all. In such a case, the question of "compartmentation" doesn't really arise—the system is inherently limited to a compartment or "net" of two. But this is rarely the case with ordinary codes; and some of them must have a truly worldwide distribution. So our use of compartmentation is much more flexible and less arbitrary than our use of supersession; occasionally we will set some absolute upper limit on the number of holders permissible in a given system because cryptanalysis shows that when that number is exceeded, the time to break the system is worth the hostile effort; but in general, it is the minimum needs, for intercommunication that govern the size (or, as we call it, the copy count) of a particular key list or code.

Now I have said that compartmentation and supersession are techniques basic to our whole business across the spectrum of systems we use. Their effect is to split our security systems into literally thousands of separate, frequently changing, *independent* entities. This means, of course, that the notion of "breaking the U.S. code" is sheer nonsense—the only event that could approach such catastrophic proportions for U.S. COMSEC would be covert (that is, undiscovered) penetration of our key list and code production facilities or major storage facilities. To those of you who have had some exposure to S3 and its operations, it will be evident that this would be enormously difficult to do because of access controls there and the sheer mass of undifferentiated and unassigned, and as yet unused, material involved. If there were a major overt loss—say somebody drove off with a whole truckload of our product—or to take an actual case that occurred in 1965—the crash of a courier aircraft carrying about a ton of cryptomaterial—our cost would be considerable money and confusion; but the security impact would be negligible—we simply do not use the missing material; we replace it—that is, supersede it before it is ever put into effect.

The reason I've injected these concepts of compartmentation and supersession into the middle of this discussion of codes, although they have little to do with the structure of codes themselves, is that, despite our variants, and tricks to limit traffic volume, and controls over operational procedures, *codes as a class remain by far the weakest systems we use*; and these techniques of splitting them into separate entities and throwing them out as often as possible are essential to obtaining even the limited short-term security for which most of them are intended.

Having said, in effect, that codes as a class are not much good, let me point out that there are specialized paper and pencil systems which more or less conform to the definition of "code" but which are highly secure. Before I do this, let me return to the definition of code we started from, and suggest an alternative definition which more nearly pin-points how they *really* differ from other techniques of encryption. You remember we said the thing that makes a code unique is the fact that

the code values can represent underlying values of different lengths—to recognize this is important to the cryptanalyst and that is the feature that stands out for him. But there is something even more basic and unique to a code: that is the fact that each code group—that QXB or what-have-you—stands for something that has *intrinsic meaning*, i.e., each underlying element of plain text is cognitive; it is usually a word or a phrase or a whole sentence. In every other system of encryption, this is not so; the individual cipher value stands only for an arbitrary symbol, meaningless in itself—like some binary digit or a letter of the alphabet. So I find, when examining a code, that QXB means “FIRE A GUN,” or “REGROUP AT THE CROSSROADS,” or “QUARTERBACK SNEAK,” or what-have-you. In a *cipher system*, QXB might mean “X” or “L” or “001” or something else meaningless in itself. I’ve touched on this partly because the new cryptologic glossary has defined a code in terms of the meaning—or meaningfulness—of the underlying textual elements. I wouldn’t push the distinction too far—it gets hazy when you are *spelling* with a code; get around it by admitting that, during the spelling process, you are in fact retaining a one-to-one relationship between the size of the underlying values and those being substituted for them—you are, for the moment, “enciphering” in the code.

The “One-Time” Concept.—I have said that at the heart of a code’s insecurity is the fact that it is essentially a monoalphabetic process where the same code group always stands for the same underlying plaintext value. The way to lick this, of course, is to *devise a system where each code value is used once and only once*. Repeats don’t show up because there aren’t any, and we have effectively robbed the cryptanalyst of his “entering wedge” into the cryptosystem. Let’s look at several such systems:

ARTILLERY: ABD	BRIGADE: MJX
QVM	ZTY
CXD	RDF
EVL	QLW
QSI	

	etc.

Well! This thing looks like nothing more than one of those ordinary codes we talked about, but with a set of variants assigned to each item of the vocabulary. Right. But suppose I make a rule that each time you use a variant, you check it off or cross it out, and must not use it again? By this simple expedient, I have given you a *one-time system*—a system which is for all practical purposes immune to cryptanalysis, perfectly secure? Sounds nice, and you might wonder why we have not adopted it for universal use. Well, let’s look at some of the constraints inherent in this simple procedure:

Right now, if I have a very large vocabulary in a standard two-part code, it may run up to 32 pages or more. (The largest is 64 pages). If I have to insert say a half-dozen code values for every plaintext entry, my code book gets to be about 200 pages long, rather awkward to jam in the most voluminous of fatigue pockets, and a most difficult thing to thumb through—jumping back and forth, mind you—as you do your encoding or decoding process. So, limitation number one: we have to confine the technique to codes of quite small vocabularies.

Suppose my “compartment” (my net size) is 20 holders for this code. How does any given user know which values other holders in the net have used? He doesn’t. He doesn’t unless everybody listens to everybody else all the time, and that doesn’t often happen. And this is really the killing limitation on most one-time systems of this kind. You wind up saying only *one* holder can send messages in the code, and all other copies are labelled “RECEIVE ONLY”. We call this method of communications “Broadcast” and it has rather narrow applications. Alternatively, we can provide each of our 20 holders with a SEND code and 19 RECEIVE codes—but try to visualize some guy in an operational environment scrambling through 19 books to find the right one for a given incoming message; and look at the logistics to support such a system: it turns out that the number of books you need is the *square* of the number of holders you want to serve in this way—400 books for a 20-

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holder net—10,000 for 100 holders! So limitation number two: the size of a net that you can practically operate in this way is very small: preferably just two stations.

Let's turn now to another kind of one-time code; one that we call a "pro forma" system. "Pro forma" means that the basic framework, form or format of every message text is identical or nearly so; the same kind of information, message after message, is to be presented in the same order, and only specific values, *like numbers*, change with each message.

LINE NR.	LINE TITLE	ENCRYPTION/DECRYPTION TABLE
1	TABLE INDICATOR	PGA
2	NUCLEAR ACTION FORM/SEG	<p> 01 023456789 0123456789 0123456789 0123456789 0123456789 0123456789 YZ QRSTUVWXYZ NOPQRSTUWV WXYZ ABCDEF UVWXYZ ABCD KLMNOPQRST CDEFGHIJKL ARMY ARTY CORPS CORPS DIV ARTY TASK CAV Y Z A B C D E F G H </p> <p>NULLS SYU</p>
3	TYPE ACTION	<p> NOTIFICATION REG ALERT ORDER APPR CANCEL CHANGE RECCE EMPLACE F G H I J K L M N FIRE/LAUNCH NEG AFFIRMATIVE HOLD SPARE 1 SPARE 2 D P Q R S T </p> <p>NULL M</p>
4	NUC STRIKE DSZ/TST NR	<p> 0123456789 023456789 0123456789 023456789 023456789 023456789 CDEFGHIJKL HJKLMNQPQ RSTUVWXYZA JKLMNOPQRS IJKLMNQPQR NULLS KKA </p>
5	DESIRED GROUND ZERO	<p> ABCDEFGHIJKLMNPQRSTUWXYZ ABCDEFGHIJKLMNPQRSTU 023456789 023456789 RSTUVWXYZABCDEF GHIJKLM LMNOPQRSTUWXYZABCDE NOPQRSTUWV RSTUVWXYZ 023456789 0123456789 0123456789 0123456789 023456789 0123456789 STUWXYZAB LMNOPQRSTU QPQRSTUWVX YZABCDEF GHIJKLMNQRST XYZABCDEF GHIYZABCDEF </p> <p>NULL P</p>
6	TARGET DESCRIPTION RADIUS IN METERS	<p> ABCDEFGHIJKLMNPQRSTUWXYZ ABCDEFGHIJKLMNPQRSTUWXYZ NOPQRSTUWXYZABCDEF GHIJKLM EFGHIJKLMNPQRSTUWXYZ ABCD 023456789 0123456789 023456789 023456789 023456789 RSTUVWXYZA NOPQRSTUWV WXYZABCDEF KLMNOPQRST </p> <p>NULLS TU</p>
7	TGT ELEV IN METERS	<p> 023456789 0123456789 023456789 023456789 023456789 RSTUVWXYZ WXYZ ABCDEF NOPQRSTUWV WXYZ ABCDE </p> <p>NULL C</p>
8	TYPE BURST/ METERS	<p> HIGH LOW SUR SUBSUR 023456789 023456789 023456789 023456789 O P Q R KLMNOPQRST QRSTUVWXYZ YZABCDEF GHI XYZABCDEF GHI NULLS STD </p>
9	TIME OVER TARGET	<p> 02 0123456789 0123456789 0123456789 0123456789 023456789 LOCAL GMT QRST VWXYZ ABCDE XA STUWXYZAB NOPQRS RSTUVWXYZ L M NULL C </p>
10	DELIVERY MEANS	<p> AIR KJ 8IN-H NIKE-H 155 SET LJ RESTN LANCE DAVY CROCKETT B C D E F G H I J K PERSH ADM SPARE 1 SPARE 2 SPARE 3 SPARE 4 L M N O P Q NULL J </p>
11	WEAPON (MK NR)	<p> 023456789 023456789 023456789 023456789 IJKLMNQPQR TUVWXYZABC IJKLMNQPQR NULLS GV </p>
12	YIELD	<p> KT MT 023456789 023456789 023456789 DECIMAL POINT X Y GHIJKLMNQP IJKLMNQPQR GHIJKLMNQP 0123456789 023456789 023456789 023456789 FGHIJKLMNO WXYZABCDEF FGHJKLMNO NULLS VTB </p>
13	LOCATION OF FIRING POINT	<p> ABCDEFGHIJKLMNPQRSTUWXYZ ABCDEFGHIJKLMNPQRSTU 023456789 023456789 ZABCDEF GHIJKLMNQPQRSTUWV XYZABCDEF GHIJKLMNQPQ RSTUVWXYZ 0123456789 023456789 0123456789 0123456789 023456789 023456789 PQRSTUWXYZ YZABCDEF GHI WXYZ ABCDE FGHIJKLMNO ZABCDEF GHI PQRSTUWXYZ NULL G </p>
14	FRIENDLY FORCES SFTY CRIT/ DEGREE RISK EMERGENCY	<p> BARNED UNWARNED OPEN WOODS FOXHOLES SHELTERS TANKS BLDGS VEH P Q R V W X Y Z A NEGLIGIBLE A B NULLS RG </p>
15	AZ IN MILS/ METERS DGZ TO FRIENDLY FORCES	<p> 023456 023456789 0123456789 0123456789 023456789 023456789 NOPQRST IJKLMNQPQR MNOPQRSTUWV WXYZ ABCDEF KLMNOPQRST TUVWXYZABC 023456789 023456789 023456789 OPQRSTUWXYZ CDEFGHIJKL NULLS FUP </p>

Now we're beginning to get something more manageable: We still have the constraint of needing small net size or, alternatively, a larger net but with only one or a few senders of information. But it's a dandy where the form of the messages themselves permit this terrible inflexibility. We use a few of them, but machines are the things we're moving towards to meet most of the requirements of this type.

The last one-time code system I want to talk about is one that we use a great deal for Direction Finding Operations. We call it COMUS—which reminds me that we will soon have to come to grips with *nomenclature*—perhaps in the next hour.

	1 2 3 4 5 6 7 8 9 0		ABCDEFGHIJKLMN	OPQRSTU	VWXYZ0123456789
FREQUENCY	G J F H I D A E B C	CALL SIGN	UV64K8082LEJ7CG5NYTSAB1ZRXHWI9DP	CMF3	
	1 2 3 4 5 6 7 8 9 0		ABCDEFGHIJKLMN	OPQRSTU	VWXYZ0123456789
	A B I J E G H C D F		FMIDTA5ZC48YB86WDX2E97PRLHK3S1JGOVNU		
	1 2 3 4 5 6 7 8 9 0		ABCDEFGHIJKLMN	OPQRSTU	VWXYZ0123456789
	G F I H J A E D C B		9WL7DUZMTFPCHEK48NIF1B23G6VXYOJ0DRA		
	1 2 3 4 5 6 7 8 9 0		ABCDEFGHIJKLMN	OPQRSTU	VWXYZ0123456789
	D I H C G F A E B J		KLOX54ZSV3ABF2CYRQH81IBDPGTUNJ9E76W4		
	1 2 3 4 5 6 7 8 9 0		ABCDEFGHIJKLMN	OPQRSTU	VWXYZ0123456789
	C E B F H I J A G D		64ENCUI2G550ZDY7XTVRF53OCMLBHWBKAPIJ		
TRACKING	M S G E D X C O O V U 9 A T H 2 I 0		S T U V W X Y Z 0 1 2 3 4 5 6 7 8 9		
BRG RPT			B N K J 3 F Z Y R 5 P W 7 1 8 4 6 L		
A	SUKTP LFXVBSGRKNIH LZDSITAEKXN OHULKANKGEB		OCB034PPFWLD VJTFIOCRSMD TAJQMSYECWZ A		
B	OCRKZ FDCJSPMCIUL DHSGONOERJE SIZDBWLCAEV		MLWTFPCUYKX JGNFUOYMRHP ZARXVTENBYO B		
C	XNIOU OPESVBJLKT PJMOANFYUSC MSIOEZCURDG		GCVAZTDCXEF LWNKFFHQVB WRYZMOUDCAG C		
D	INMRZ OYDSTUWRACQ YUWIDZXGHPA FYHOPTDMUIB		FCLMTSNOCRE SNRACXQVZLE KBGEFNZMPJV D		
E	PSLMV FXHRTIYAQJC JYTMHVEAOD KBSCJZHEDN		LXGDCZCPFRS1 UWQFOIXYVGT WNPEKQVOMUG E		
F	YTGIU LWXSZONDAOH XNCKEUQYIOH FWKESRJIVYQ		VJMTRWBALDF HTUADRLMBCZ KFTCVIYBJEP F		
G	YNEBI UCQKRGPI MJ JVRIWTZLYHK GKEJCFDTPYS		HQXESUEDCAS MILOGZURHNV TFBZVEYHOWX G		
H	NRLVO YSKFGAWEDBP FHCLYDGGEXB AINYPWFQUTG		UPJTHIKCRA OLEXSMBCDZJ TUVCDQNI XM H		
I	MURXI OHWDEGYRZBC WIGFZUTXMHC AKUBHYHREFI		AQLKYBPSLV QNPSZLDTXVC MAJIVPXNKST I		

In comparing this one-time system and the last one I showed you, I think you'll begin to see a number of characteristics emerge for these specialized codes: first off, they are relatively secure: I say relatively, because there is more to communications security than resistance to cryptanalysis—and while these systems meet that first test—cryptanalysis—admirably, from the *transmission security* point of view, they're pretty bad; but we'll be talking about that on another day. Secondly: they are inflexible, rigidly confined with respect to the variety of intelligence they can convey. Thirdly: they are built for *speed*; they are by far the fastest means of communicating securely without a machine. Finally, they are extremely specialized, narrow in their application, and limited in the size of communications network they can serve efficiently. Being specialized, by the way, and *tailored* to particular needs, they fly in the face of efforts to *standardize* our materials—a very necessary movement in a business where we have to make hundreds of codes, distribute them all over the world, replace most of them daily and, as a result, wind up with a total copy count numbering, at the moment, about 5 million each year.

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The business of standardizing on the one hand, for the sake of economy, simplicity, and manageability and of uniquely tailoring systems for maximum efficiency in some particular application, is one of the many conflicting or contradictory themes in our business; just as maximum security may conflict with speed or something else.

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ORIGINAL 19
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SECOND LECTURE:

Codes

So far we have been talking about general and specialized codes; they form the largest body of manual systems we have. There are several more types of manual systems, but before we turn to them, there are a few more associations I want you to form with codes. So far we've limited ourselves pretty much to how they work and have hinted at some of their security and operational shortcomings, and have only implicitly indicated where they are used or why they'd be preferable to something automatic like a machine.

By far the biggest use of codes we have is with *voice* communications, with field telephones over wire lines or with radio telephones. The foremost reason for our reliance on them in these applications is because we do not yet have, in quantity, the voice encryption equipment that will be needed to replace them. When we discuss voice encryption equipment—cipphony machines—you will see some of the real technical, operational, and cost considerations which have kept them relatively scarce. For the moment, it is sufficient to remember that their lack is the main reason for the extensive use of codes and for a worse security situation, the use of no cryptography at all—plain language. Even where a unit might be able to afford machine cryptography, codes are sometimes attractive for other reasons—they are generally cheap (a few cents a copy); highly compact and portable (many of them do find their way into pockets and map cases); simple—they require no maintenance, hardly any training, and no power; easily disposed of—just touch a match to them. You can carry them anywhere and use them on any communications system at your disposal.

You will find them most at the lowest echelons; the Army is by far their largest user; they have considerable use in aircraft that don't now have the room or compatible communications systems to work with cryptomachines.

Aside from the security shortcomings of codes, they have one other very serious disadvantage: that is, they are very *slow*, ordinarily permitting the encryption of only a few words a minute, while most machines will operate at least as fast as you can type. Finally, even codes with very large vocabularies are awkward and inflexible because not all the right words are there, with the result that messages may be clumsy and imprecise as well as slow.

The next kind of manual system I want to talk about is the *one-time pad*. One-time pads are pure and simple cipher systems (*not* codes); with a one for one replacement of each plaintext character by a cipher equivalent. They consist of page after page of random numbers or letters (which call one-time key). The oldest type still in substantial use is called DIANA. Here's a sample.

LFHNY ZAMSE JRNKE BYMFW KOZAT
VRETH JPCSU RUSYG JWKMN WLOEL
PODYW JLVUJ XFSKL MPLGA ZXYZY
TSUIO XBMKI HBSND MPNPI OZVOZ
EYJFW OBXKR PNTYY YTKGK ATOPE
NHCKJ FPNSV SMZZN QQZYN CYSDE
YIIUJ TWRZ QHRDE YOVRJ MOCGY
HALOK NHIIN CAIDV RDTKH ZDZMP
OINDS CMOFEXEBVJ CAYSO ISBMU
KLSZX OZJIM DBRCY BNUVZ LFBXT
YKTI WIFH IHNSF RUVVC UITRN
NQQNG ZUBZB EPVJX NCZZY FBTEX
VEIOE HDVTN GSSNG LRZWG UKUGK
POFRI QCFAA NLTKE DANDA QAIMU
HEING LDTWP NVBNX MNUUK ACPKA
AYGFB ZNFDU SYNVX IYIPD RJCEK
PROPO JFBIO NYLIX GWTNC QQXXH
FSGNA UDTLB UNKAN HARKG TZYXN
UGBOA JXMFY HTUNH WCTXM OFLSY

A	ABCDEFGHIJKLMN	OPQRSTUVWXYZ	
B	ZYXWVUTSRQP	ONMLKJIHGFE	DCBA
C	ABCDEFGHIJKLMN	OPQRSTUVWXYZ	
D	XWVUTSRQPON	MLKJIHGFE	DCBAZY
E	ABCDEFGHIJKLMN	OPQRSTUVWXYZ	
F	VUTSRQPONML	KJIHGFE	DCBAZYXW
G	ABCDEFGHIJKLMN	OPQRSTUVWXYZ	
H	TSRQPONMLKJ	IHGFE	DCBAZYXWVU
I	ABCDEFGHIJKLMN	OPQRSTUVWXYZ	
J	SRQPONMLKJI	HGFE	DCBAZYXWVUT
K	ABCDEFGHIJKLMN	OPQRSTUVWXYZ	
L	RQPONMLKJI	HGFE	DCBAZYXWVUTSR
M	ABCDEFGHIJKLMN	OPQRSTUVWXYZ	
N	QONMLKJIHG	FEDCBAZY	XWVUTSR
O	ABCDEFGHIJKLMN	OPQRSTUVWXYZ	
P	LKJIHGFE	DCBAZYXW	VUTSRQPONM
Q	ABCDEFGHIJKLMN	OPQRSTUVWXYZ	
R	KJIHGFE	DCBAZYXW	VUTSRQPONML
S	ABCDEFGHIJKLMN	OPQRSTUVWXYZ	
T	JHGFE	DCBAZYXW	VUTSRQPONMLK
U	ABCDEFGHIJKLMN	OPQRSTUVWXYZ	
V	GFEDCBAZY	XWVUTSRQP	ONMLKJI
W	ABCDEFGHIJKLMN	OPQRSTUVWXYZ	
X	EDCBAZYXW	VUTSRQPON	MLKJIHGFE
Y	ABCDEFGHIJKLMN	OPQRSTUVWXYZ	
Z	DCBAZYXW	VUTSRQPON	MLKJIHGFE

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50 U.S.C. 3605 (P.L. 86-36)

So, where volume is very low, for example in a place where pads are held only as an emergency back-up to machine systems and used only when the machines fail, one pad could remain "effective" for years.

One-time pads have undergone a kind of evolution during the past decade or so. The main effort has been to find ways of obtaining more speed. The first major pad system after DIANA did provide a good deal more speed—it is called ORION, and it's three times as fast.

K P O R S T U V W X Y Z A B C D E F G H I J K L M N O
 P Q R S T U V W X Y Z A B C D E F G H I J K L M N O
 C D E F G H I J K L M N O P Q R S T U V W X Y Z A B
 C D E F G H I J K L M N O P Q R S T U V W X Y Z A B
 C D E F G H I J K L M N O P Q R S T U V W X Y Z A B
 I J K L M N O P Q R S T U V W X Y Z A B C D E F G H
 F G H I J K L M N O P Q R S T U V W X Y Z A B C D E
 I J K L M N O P Q R S T U V W X Y Z A B C D E F G H I
 J K L M N O P Q R S T U V W X Y Z A B C D E F G H I
 L M N O P Q R S T U V W X Y Z A B C D E F G H I J K
 P Q R S T U V W X Y Z A B C D E F G H I J K L M N O
 Y Z A B C D E F G H I J K L M N O P Q R S T U V W X
 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
 M N O P Q R S T U V W X Y Z A B C D E F G H I J K L
 T U V W X Y Z A B C D E F G H I J K L M N O P Q R S
 T U V W X Y Z A B C D E F G H I J K L M N O P Q R S
 D E F G H I J K L M N O P Q R S T U V W X Y Z A B C
 G H I J K L M N O P Q R S T U V W X Y Z A B C D E F
 Y Z A B C D E F G H I J K L M N O P Q R S T U V W X
 Y Z A B C D E F G H I J K L M N O P Q R S T U V W X
 K L M N O P Q R S T U V W X Y Z A B C D E F G H I J
 V W X Y Z A B C D E F G H I J K L M N O P Q R S T U
 V W X Y Z A B C D E F G H I J K L M N O P Q R S T U
 R O P Q R S T U V W X Y Z A B C D E F G H I J K L M
 Z A B C D E F G H I J K L M N O P Q R S T U V W X Y
 P Q R S T U V W X Y Z A B C D E F G H I J K L M N O
 O P Q R S T U V W X Y Z A B C D E F G H I J K L M N
 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
 C D E F G H I J K L M N O P Q R S T U V W X Y Z A B
 G H I J K L M N O P Q R S T U V W X Y Z A B C D E F
 K L M N O P Q R S T U V W X Y Z A B C D E F G H I J
 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
 H I J K L M N O P Q R S T U V W X Y Z A B C D E F G
 M I J K L M N O P Q R S T U V W X Y Z A B C D E F G
 P Q R S T U V W X Y Z A B C D E F G H I J K L M N O
 M N O P Q R S T U V W X Y Z A B C D E F G H I J K L
 O P Q R S T U V W X Y Z A B C D E F G H I J K L M
 N O P Q R S T U V W X Y Z A B C D E F G H I J K L M
 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
 Y Z A B C D E F G H I J K L M N O P Q R S T U V W
 V W X Y Z A B C D E F G H I J K L M N O P Q R S T U
 L M N O P Q R S T U V W X Y Z A B C D E F G H I J K
 P Q R S T U V W X Y Z A B C D E F G H I J K L M N O
 H I J K L M N O P Q R S T U V W X Y Z A B C D E F G
 J K L M N O P Q R S T U V W X Y Z A B C D E F G H I
 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
 G H I J K L M N O P Q R S T U V W X Y Z A B C D E F
 T U V W X Y Z A B C D E F G H I J K L M N O P Q R S

K P O R S T U V W X Y Z A B C D E F G H I J K L M N O
 P Q R S T U V W X Y Z A B C D E F G H I J K L M N O
 C D E F G H I J K L M N O P Q R S T U V W X Y Z A B
 C D E F G H I J K L M N O P Q R S T U V W X Y Z A B
 C D E F G H I J K L M N O P Q R S T U V W X Y Z A B
 I J K L M N O P Q R S T U V W X Y Z A B C D E F G H
 F G H I J K L M N O P Q R S T U V W X Y Z A B C D E
 I J K L M N O P Q R S T U V W X Y Z A B C D E F G H I
 J K L M N O P Q R S T U V W X Y Z A B C D E F G H I
 L M N O P Q R S T U V W X Y Z A B C D E F G H I J K
 P Q R S T U V W X Y Z A B C D E F G H I J K L M N O
 Y Z A B C D E F G H I J K L M N O P Q R S T U V W X
 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
 M N O P Q R S T U V W X Y Z A B C D E F G H I J K L
 T U V W X Y Z A B C D E F G H I J K L M N O P Q R S
 T U V W X Y Z A B C D E F G H I J K L M N O P Q R S
 D E F G H I J K L M N O P Q R S T U V W X Y Z A B C
 G H I J K L M N O P Q R S T U V W X Y Z A B C D E F
 Y Z A B C D E F G H I J K L M N O P Q R S T U V W X
 Y Z A B C D E F G H I J K L M N O P Q R S T U V W X
 K L M N O P Q R S T U V W X Y Z A B C D E F G H I J
 V W X Y Z A B C D E F G H I J K L M N O P Q R S T U
 V W X Y Z A B C D E F G H I J K L M N O P Q R S T U
 R O P Q R S T U V W X Y Z A B C D E F G H I J K L M
 Z A B C D E F G H I J K L M N O P Q R S T U V W X Y
 P Q R S T U V W X Y Z A B C D E F G H I J K L M N O
 O P Q R S T U V W X Y Z A B C D E F G H I J K L M N
 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
 C D E F G H I J K L M N O P Q R S T U V W X Y Z A B
 G H I J K L M N O P Q R S T U V W X Y Z A B C D E F
 K L M N O P Q R S T U V W X Y Z A B C D E F G H I J
 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
 H I J K L M N O P Q R S T U V W X Y Z A B C D E F G
 M I J K L M N O P Q R S T U V W X Y Z A B C D E F G
 P Q R S T U V W X Y Z A B C D E F G H I J K L M N O
 M N O P Q R S T U V W X Y Z A B C D E F G H I J K L
 O P Q R S T U V W X Y Z A B C D E F G H I J K L M
 N O P Q R S T U V W X Y Z A B C D E F G H I J K L M
 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
 Y Z A B C D E F G H I J K L M N O P Q R S T U V W
 V W X Y Z A B C D E F G H I J K L M N O P Q R S T U
 L M N O P Q R S T U V W X Y Z A B C D E F G H I J K
 P Q R S T U V W X Y Z A B C D E F G H I J K L M N O
 H I J K L M N O P Q R S T U V W X Y Z A B C D E F G
 J K L M N O P Q R S T U V W X Y Z A B C D E F G H I
 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
 G H I J K L M N O P Q R S T U V W X Y Z A B C D E F
 T U V W X Y Z A B C D E F G H I J K L M N O P Q R S

To understand how the ORION pad is used, it will be helpful to visualize the two illustrations shown above as being printed in exact alignment on reverse sides of the same sheet of paper. To encipher, one sheet of the pad with the straight alphabet side up is placed on a piece of carbon paper, carbon side up. With this arrangement, when a plaintext letter is circled on one side of the paper, a circle will appear on the other side of the paper as surrounding the cipher letter because of the carbon paper. Therefore, by recording the text of the message—one letter per line—on the plaintext alphabet, the enciphered text is available by merely turning over the page.

Here we are able to encipher as quickly as we can circle the letters of our plain text—and because we have reciprocity, the deciphering process is equally fast. But, as usually seems to happen to us with manual systems, we have achieved speed at a very considerable cost in bulk—we have lost the means to compress a great deal of key in a small space. With DIANA, we were able to encipher about 100 words with each page; with this system, only 10 words. All of a sudden we have had to print 26 letters of key for each one letter of plain text, and the result is that the user is stuck with a very large batch of material to store and account for if he has to process many messages. Still, where speed is of the essence, where no machine is available, and where messages are very short or infrequent, the system found a place. You'll note, though, that such a pad entails a very tricky production process. The alphabets on the front and back of each page must be in exact alignment—"registration" the printers call it. This slowed down the printing process so much, and was so costly, that we have stopped producing ORION pads, although a number of them are still in use in the field. What we came up with instead is a system equally fast, and easier to make called MEDEA.

01 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 PONMLKJIHG FEDCBA9876543210ZYXWVUTSRQ

02 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 IHGFEDCBA9876543210ZYXWVUTSRQPONMLKJ

03 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 LKJIHG FEDCBA9876543210ZYXWVUTSRQPONM

04 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 JIHGFEDCBA9876543210ZYXWVUTSRQPONMLK

05 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 BA9876543210ZYXWVUTSRQPONMLKJIHG FEDC

06 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 EDCBA9876543210ZYXWVUTSRQPONMLKJIHG F

07 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 543210ZYXWVUTSRQPONMLKJIHG FEDCBA9876

08 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 WVUTSRQPONMLKJIHG FEDCBA9876543210ZYX

09 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 RQPONMLKJIHG FEDCBA9876543210ZYXWVUTS

10 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 GFEDCBA9876543210ZYXWVUTSRQPONMLKJIH

11 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 QPONMLKJIHG FEDCBA9876543210ZYXWVUTSR

12 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 HGFEDCBA9876543210ZYXWVUTSRQPONMLKJI

13 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 JIHGFEDCBA9876543210ZYXWVUTSRQPONMLK

14 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 YXWVUTSRQPONMLKJIHG FEDCBA9876543210Z

15 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 0ZYXWVUTSRQPONMLKJIHG FEDCBA987654321

16 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 UTSRQPONMLKJIHG FEDCBA9876543210ZYXWV

17 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 6543210ZYXWVUTSRQPONMLKJIHG FEDCBA987

18 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 10ZYXWVUTSRQPONMLKJIHG FEDCBA98765432

19 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 TSRQPONMLKJIHG FEDCBA9876543210ZYXWVU

20 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 210ZYXWVUTSRQPONMLKJIHG FEDCBA9876543

21 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 76543210ZYXWVUTSRQPONMLKJIHG FEDCBA98

22 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 A9876543210ZYXWVUTSRQPONMLKJIHG FEDCB

23 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 RQPONMLKJIHG FEDCBA9876543210ZYXWVUTS

24 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 XWVUTSRQPONMLKJIHG FEDCBA9876543210ZY

25 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 0ZYXWVUTSRQPONMLKJIHG FEDCBA987654321

26 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 NMLKJIHG FEDCBA9876543210ZYXWVUTSRQPO

27 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 ZYXWVUTSRQPONMLKJIHG FEDCBA9876543210

28 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 3210ZYXWVUTSRQPONMLKJIHG FEDCBA987654

29 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 FEDCBA9876543210ZYXWVUTSRQPONMLKJIHG

30 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 LKJIHG FEDCBA9876543210ZYXWVUTSRQPONM

31 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 210ZYXWVUTSRQPONMLKJIHG FEDCBA9876543

32 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 43210ZYXWVUTSRQPONMLKJIHG FEDCBA98765

33 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 GFEDCBA9876543210ZYXWVUTSRQPONMLKJIH

34 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 6543210ZYXWVUTSRQPONMLKJIHG FEDCBA987

35 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 43210ZYXWVUTSRQPONMLKJIHG FEDCBA98765

36 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 EDCBA9876543210ZYXWVUTSRQPONMLKJIHG F

37 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 ZYXWVUTSRQPONMLKJIHG FEDCBA9876543210

38 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 GFEDCBA9876543210ZYXWVUTSRQPONMLKJIH

39 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 10ZYXWVUTSRQPONMLKJIHG FEDCBA98765432

40 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 CBA9876543210ZYXWVUTSRQPONMLKJIHG FED

41 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 WVUTSRQPONMLKJIHG FEDCBA9876543210ZYX

42 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 DCBA9876543210ZYXWVUTSRQPONMLKJIHG FE

43 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 DCBA9876543210ZYXWVUTSRQPONMLKJIHG FE

44 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 JIHGFEDCBA9876543210ZYXWVUTSRQPONMLK

45 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 GFEDCBA9876543210ZYXWVUTSRQPONMLKJIH

46 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 TSRQPONMLKJIHG FEDCBA9876543210ZYXWVU

47 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 SRQPONMLKJIHG FEDCBA9876543210ZYXWVUT

48 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 ONMLKJIHG FEDCBA9876543210ZYXWVUTSRQP

49 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 GFEDCBA9876543210ZYXWVUTSRQPONMLKJIH

50 ABCDEFGHIJ KLMNOPQRSTU VWXYZ0123456789
 HGFEDCBA9876543210ZYXWVUTSRQPONMLKJI

This system looks a lot like that one I showed you for D/F work (COMUS). It, and variations of it, are fairly common these days. Because of its smaller bulk, though, DIANA, and its numerical equivalent (CALYPSO) are still the most used one-time pads.

Now, where are one-time pads used? Not in a single-seater aircraft, surely! And rarely in big cryptocenters where machines are available—sometimes, though, officials need complete privacy for especially sensitive messages; they don't want them read by the cryptographers or others in the communications center, and will use a pad for the most sensitive portions of their message. The communication center will then superencrypt it (encrypt it again) in a machine system. But this is not a very common practice. The main use of pads is in connection with intelligence, agent, or

The first thing you ought to grasp conceptually about the process of authentication is that it takes two principal forms—*challenge and reply* where the sender and recipient are in radio or wire contact with one another and can interrogate each other according to some system of authentication to establish their respective bona fides. The other and more difficult form of authentication is called *message authentication* in which the message itself carries with it *something* that tells the recipient that the message he has received is really intended for him and came from a legitimate source. We need this latter protection to prevent hostile intercept activities from faking messages altogether or picking up legitimate messages but *changing* their addresses so the wrong people will try to act on their contents.

The second thing to note about the authentication process is that it finds its greatest application where there is no cryptographic protection for the basic message text. Where full-scale machine cryptography can be employed on line, the basic cryptosystem "authenticates" the message. The message would not decrypt unless the sender had the key, and he would not have the key unless he was one of ours.

The third thing to remember about authentication systems is that there is one feature inherent in them that presents an extreme challenge to the group charged with inventing them—manual authentication systems must be swift and simple; but inherent in the process is the need to give the hostile analysts *both* the plain language (challenge) and the cipher text (the reply). To get ahead of ourselves for a moment, most modern sophisticated crypto-equipments are now good enough that we can hand the hostile analyst reams of our plain language and exactly matched cipher text to go with it, and still not provide him the basis for reconstructing the basic key or recovering any ungiven plain language. But our older machines could not stand up when the enemy was given the opportunity to match up plain language with its corresponding cipher, and we had to go to rather elaborate means to prevent this from happening. With simple manual systems, the difficulty, when you have to expose both your plain text and your cipher text, is even greater; yet that's exactly what we're being asked to do in any authentication system. For when you challenge with, "What is the authentication of ALFA BRAVO?" you are really saying, "What is the encipherment of ALFA BRAVO?" and the recipient is really replying that ALFA BRAVO enciphers to "CHARLIE NOVEMBER" or what have you. The result has been that most of our authentication systems over the years have been not very fast, or not very secure, or limited to very small networks.

25X3, E.O.13526

Withheld from public release under
§6 of the National Security Act of 1959,
50 U.S.C. 3605 (P.L. 86-36)

The primary authentication system used worldwide between and among ships, aircraft and forces is called TRITON. This system is illustrated below:

A	RLCVJFTZQNXDHOKEGYSUPIAMWBYJAC	18-1
B	EUYNKWMLBVHTSCQJIFARZGXPOOHSX	19-2
C	AEOKPXUTJLSRQYIWFGBHNVZDPGWK	20-4
D	RGSZOAVHCINKLXFQJBYMUDEWPTUPHG	21-1
E	TYFCKPEWQAJMXOGVNZUHSOBI LR TIVN	22-2
F	LJAPEQZMTFYWONKBSHXGRUDVICEQAI	23-3
G	TDNXGFESKROIABHVMJUQCLZWYPXQMH	
H	NVRQEIJDHOPLXWCGSFKUZATBOKGM	
I	HOZFUOCRADYXKPJVNGMLBISWETEVBUI	
J	QDLHJOWNCUZKSABEMRFVXYIPGTOWNU	
K	PSYKWHRCGOMIOBAVLTNQXFZEUJVEOR	
L	JWFKEAVMXSTOUCRIGBOLZHYPGNOWGH	
M	JYDZBIOENTHQGLCMKAXUPFRWSVHCLV	00-8
N	VXFLJBCRGMHIZYEQASWTKUODNXP DAR	02-5
O	FZWMYQAJLTPVUIBDSQNRGKHXCBFNR	04-7
P	TASCIRGBJWQVEUHKYMOXFLNDZPPNLY	06-0
Q	PFZNYMXKSHCLBIVRGAUTEQQJDR LHK	08-0
R	ONCSLDVURIHWJEBGFXYATYPKQHZFUKT	10-4
S	EFWBVTSZIHQNJAOYCM LDXURPKGNVVA	12-6
T	RUEYZSQMOLFVOKTXHAPWB JGCNIOWTP	14-1
U	RFWJHTBDYSKEVZUOLIGANXPCQMWNTJ	16-9
V	VYPQKHLBZXFIMACTESOWDJGRNUMYPW	18-3
W	RHDYPTIWZGLKONUXBEQSCVFM AJLENW	20-6
X	LHFRVYKDOSEFWIZMJNCOTGBXAUOIXP	22-3
Y	JBVAXNLKWODHUSFQTYMREZIPGCHUZO	24-1
Z	JHZBIFRWGCUPLTSDVXYQOAE MNKVTBS	26-8
0	MCNTKZRIUVJDYSEXQWBOHPLFAGPVKA	28-9
1	UKHYLIQWVXJZFFGMCTADNORBSEOV DN	30-5
2	PIDQUTESXANGZHYFWVMKLJOCBRPNKS	32-5
3	BGIWQMLFJZOXSHDNVCUPKTYERAAYGO	34-8
4	FXGACOSIVYGNWEBTKMUHJLZDPRVAPI	36-1
5	NZFFVYOARSKI GTUPMDQWBLJCHEXPMRX	38-6
6	BLDAUFWJCGZMRNEXSKOQYVITHPKDQZ	40-4
7	NLAYDMIGWVOQRKEJHPFZBUXTC SXKJH	42-2
8	ZYL VXUNQROEBI WPGACJTFKSMHDMYSP	44-2
9	JRTPQAKDGLUXONB WSEYVMCFIZQLDH	46-9
	ACPUMDXHJYTQGISBZEV LNKWORFMZQC	48-7
	PRJCVOKHASTFDQLMWZBIXNGUYECAFW	50-3
	IPVLNBWFGKJQOYMUZH XACTERDSIGHD	52-0
	QBLOGJEMICNYVZPKTRXSUFHWADPUKJ	54-7
	RJYNXPVEDBMGOUCSFHZIWKLTAQH KPI	56-4
	ZASCNQTMJKRGLBPVHYWIEUOXDFKYCI	58-2
	DAY 02 1800-2359 KAA-29 EV /TSEC	

DAY 2 1800-2359

A system such as TRITON introduces the notion of a "guess factor." Because the reply is two letters, there are 26² possible answers (676) for a given challenge, but the internal structure of the system provides as many as twelve correct replies for a given challenge. This means that the opponent can guess with one change in fifty-six (676 ÷ 12) of being correct. What all this means is that in a real-time authentication, we have to settle for far less than perfect security. We do this to get something that can be used fairly quickly and by a great many people using the same table. In 1974, the TRITON System will be replaced, worldwide, with the authentication system we call PELE (pronounced PAYLAY). The PELE System, illustrated next is simpler and faster than the TRITON System. But, as always seems to be the case in COMSEC, this advantage in simplicity and speed was achieved at the sacrifice of some security. With the PELE System, the guess factor is reduced to one chance in twenty-six because the reply is only one letter.

ABCDEFGHIJKLMNOPQRSTUVWXYZ	DAY 18		KVA 2888 A	
	00-00	01-01	02-02	03-03
A	00-00	01-01	02-02	03-03
B	01-01	02-02	03-03	04-04
C	02-02	03-03	04-04	05-05
D	03-03	04-04	05-05	06-06
E	04-04	05-05	06-06	07-07
F	05-05	06-06	07-07	08-08
G	06-06	07-07	08-08	09-09
H	07-07	08-08	09-09	10-10
I	08-08	09-09	10-10	11-11
J	09-09	10-10	11-11	12-12
K	10-10	11-11	12-12	13-13
L	11-11	12-12	13-13	14-14
M	12-12	13-13	14-14	15-15
N	13-13	14-14	15-15	16-16
O	14-14	15-15	16-16	17-17
P	15-15	16-16	17-17	18-18
Q	16-16	17-17	18-18	19-19
R	17-17	18-18	19-19	20-20
S	18-18	19-19	20-20	21-21
T	19-19	20-20	21-21	22-22
U	20-20	21-21	22-22	23-23
V	21-21	22-22	23-23	24-24
W	22-22	23-23	24-24	25-25
X	23-23	24-24	25-25	26-26
Y	24-24	25-25	26-26	27-27
Z	25-25	26-26	27-27	28-28

DAY 18 KVA 2888 A
FOR OFFICIAL USE ONLY

You may wonder if it is a good idea to replace the TRITON System with its guess factor of one in fifty-six by a system having a guess factor of one in twenty-six. It is. The holders of TRITON are not using it very much because of its intricate operation. We expect the PELE System to be used far more than TRITON ever was. Here is a COMSEC fact of life for you: A system offering perfect security which is so complicated that the holder of the system cannot (or will not) use it, offers the same degree of security as no system at all.

The last type of authentication system that I want to touch on just briefly is a "one-time" system with the usual great security and narrow applicability. It's called BAMBOO TREE-KAA-101, and looks like this.

BAMBOO TREE
AUTHENTICATION SYSTEM #1

ACFT IN,			
ACFT OUT,			
	ATC	GCA	
1. R G	9.2 O	17. R 5	23. O X
2. U H	18. A C	18. G I	26. U M
3. E C	11. J L	19. H Y	27. C K
4. W A	12. N N	20. J D	28. W F
5. H D	13.5 I	21. D K	29. P U
6. M X	14. M Y	22. Z W	30. N D
7. T K	15. O R	23. D V	31. V S
8. F Y	16. C B	24. C W	32. N O

The difficulty with a system such as this is an administrative one—it demands very careful allocation of a small batch of authenticators for each pilot; they have to be assigned to each flight day and these assignments have to be controlled by the ground stations. Pilots cannot authenticate each other—that is, there's no air-to-air authentication capability because pilots cannot carry so large a deck or, even if they did, they don't have time to search through 1000's of cards to validate a particular authenticator.

Before leaving this section, I think a few remarks are in order to put the business of imitative communications deception in perspective for you. There is no doubt that many of our communications are susceptible to spoofing as evidenced by the imitative communications deception activities of the Viet Cong and the North Vietnamese Army during the war in Viet Nam. I have already given you a live example of some of the techniques they used. I think you will find the following extract both interesting and informative. It is taken, verbatim, from the COMFEY STEED 1-73 JANUARY SUMMARY prepared by the Air Force Special Communications Center.

Imitative Communications Deception

This detailed knowledge of our unsecured tactical voice communications which the VC/NVA possess also contributes to their capability to use imitative communications deception as a tactical weapon. VC/NVA attempts at imitative communications deception, some of which have been successful, include attempts to lure rescue forces into traps, to shift artillery fire support to other targets, to cancel requests for assistance, to order ARVN patrols into positions susceptible to ambush, and to misroute strike aircraft; in addition to general harassment, interference and transmissions of a psychological warfare nature. Instances of sophisticated use of imitative communications deception have been detected and confirmed during the past two years.

In December 1966 an ARVN patrol received a call purportedly from subsector headquarters directing the patrol to a specified location. The message proved to be false and is believed to have been sent by the Viet Cong in an attempt to lure the patrol into an ambush.

In January 1967 the Third Marine Amphibious Force reported six instances of attempted enemy imitative communications deception in one week. Enemy communicators entered the aircraft control nets, speaking English, and attempted to misroute strike aircraft.

In February 1967, during an engagement, members of MACV Advisory Team 38 requested artillery support from their Fire Direction Center. As the Fire Direction Center prepared to furnish the requested artillery support they received another call in clear and distinct English requesting the fire be shifted to another set of grid coordinates. Team 38 overheard the new request and found that the artillery fire had been redirected upon their own position. Fortunately, they were able to contact the Fire Direction Center in time to prevent a serious accident.

In April 1968, during SEAL operations, it was reported that extraction forces received a signal requesting extraction which was not transmitted by the SEAL team.

A Viet Cong returnee, platoon leader of an anti-aircraft platoon, stated that his supporting signal platoon was composed of personnel who could all speak English, and who routinely monitored Allied Forward Air Control and Provincial radio nets. They frequently entered the Forward Air Control nets and caused Allied planes to drop bombs on government troops, and then used the fact that government troops were being bombed by their own aircraft to convince them to desert and join the ranks of the Viet Cong.

Units of an Army Division operating near the Cambodian border engaged in a lengthy exchange of voice communications with a radio operator claiming to be the leader of an Australian patrol just ahead of them, when there was no Australian patrol operating in the area. The operator spoke faultless Australian-accented English and made continued efforts to get the American commander to accept him as a bona fide unit of the Allied forces.

A prisoner of war captured in February 1968 stated that his Battalion's procedure was to intercept ARVN air-to-ground and ground-to-ground communications and when the ARVN unit asked for assistance, the Viet Cong would call the assisting force and tell them to disregard the previous message as help was no longer needed. This resulted in confusion and delay and gave his unit more time to take offensive or evasive action.

These are but a few examples of the ever increasing capability of the VC/NVA to take immediate advantage of tactical intelligence derived through the intercept and analysis of our unsecured tactical voice communications. We cannot even estimate the number of attempts at imitative communications deception which have succeeded, and which have not been detected. Due to the VC/NVA successes in this field we can expect such incidents to continue as long as our tactical voice communications carry information of intelligence value to the enemy in the clear, and remain vulnerable to enemy intrusion.

We can see from the above examples that imitative communications deception was widespread in Viet Nam. But spoofing doesn't stop there. Spoofing also occurs in other parts of the world as well, but to a lesser degree because the opportunity for imitative communications deception is less in a "cold" war than in a "hot" war.

Although imitative communications deception is an on-going activity, it is not always an easy one. There is an axiom in the deception business which demands that the deception plan result in a specific action by the enemy which works to his disadvantage and to your advantage. As often as not, it's likely that the spoofing message will call for an action that seems illogical or dangerous to the recipient, and he will tend to double check if he can.

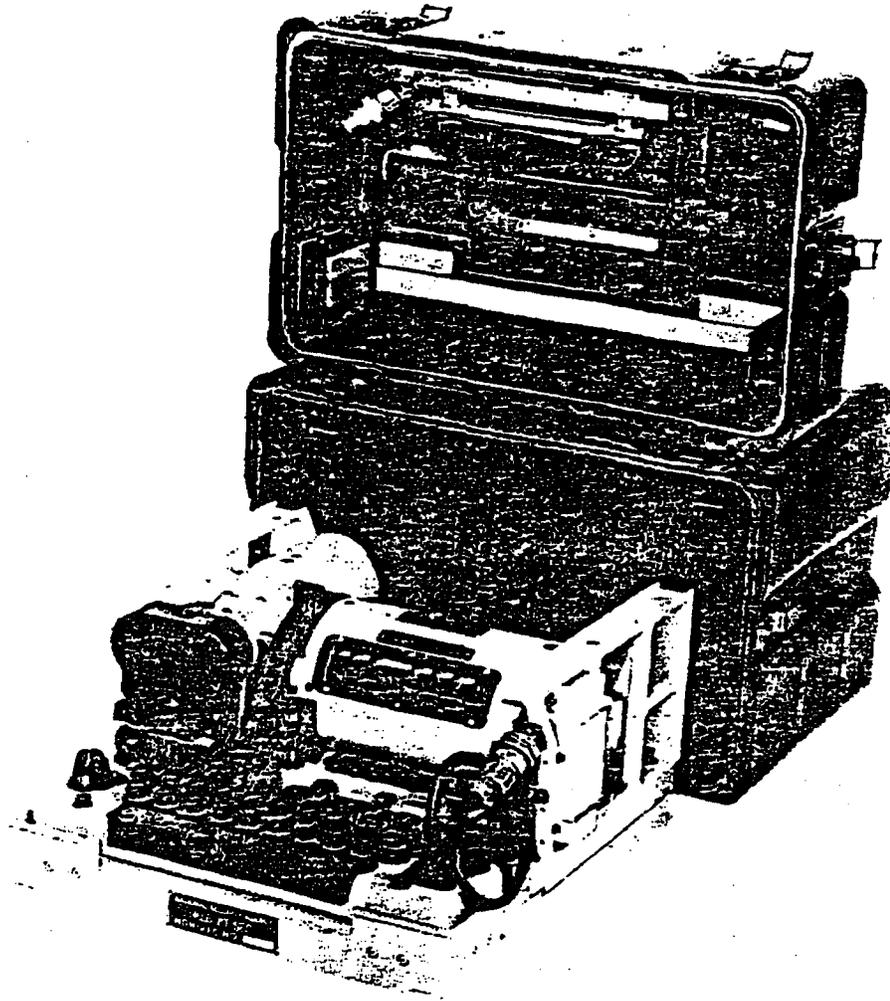
Let me now make some summary statements about manual systems as a class. First of all, they exist in great variety and I have touched only on some basic types. Second, manual systems tend to get quite specialized and tailored to specific operational requirements. Third, they are slow compared with machines; and most of the ones that serve large networks have a pretty weak security potential.

We have talked about these systems at some length because they form a numerically large part of our inventory, consume a substantial part of our total production capability, and clog our distribution and accounting pipe-lines with very large batches of material. Yet the total amount of U.S. traffic committed to these systems is paltry—our machines carry by far the lion's share of our encrypted traffic; and the great usage of manual systems is where machines can't be used for one reason or another.

THIRD LECTURE:

TSEC/KL-7

We're ready to talk now about a machine. It's called the TSEC/KL-7.



It is a *literal, off-line cipher equipment.*

Now we've got to have some definitions:

"Literal": of, pertaining to, or expressed by, letters, or alphabetic characters.

For you liberal arts students, the antonym for "literal," in our business, is not "figurative." We use literal to distinguish intelligence conveyed by letters of our alphabet from that conveyed by teletypewriter characters, speech, or digits. The output of a literal cipher machine looks like this:

DVRIT BLXMD QOGGA, etc., NOT:

++ --- +-----++ , etc., nor
011001001110010010, etc.

(However, when the communicator gets hold of the output, he may convert it to Morse code, or teletypewriter characters to facilitate its transmission.)

"Off-line" is the term we use to mean that the machine is not connected directly to the transmission path; be it a wire line or a radio transmitter. The cipher message is handed to a communicator who sends it after the whole encryption is complete, when he has time and a free circuit to reach the addressee. The opposite term is "on-line" and in this case the cipher machine is hooked directly into the transmission medium, a receiving cipher machine is hooked in at the distant end, and encryption, transmission, and decryption are performed simultaneously.

"TSEC/KL-7": I'm still trying to put off a full massage of this nomenclature business as long as possible; but let me make a beginning because this is the first really formidable set of hieroglyphics I have used on you, and you out to be aware that it is fairly systematic and formalized.

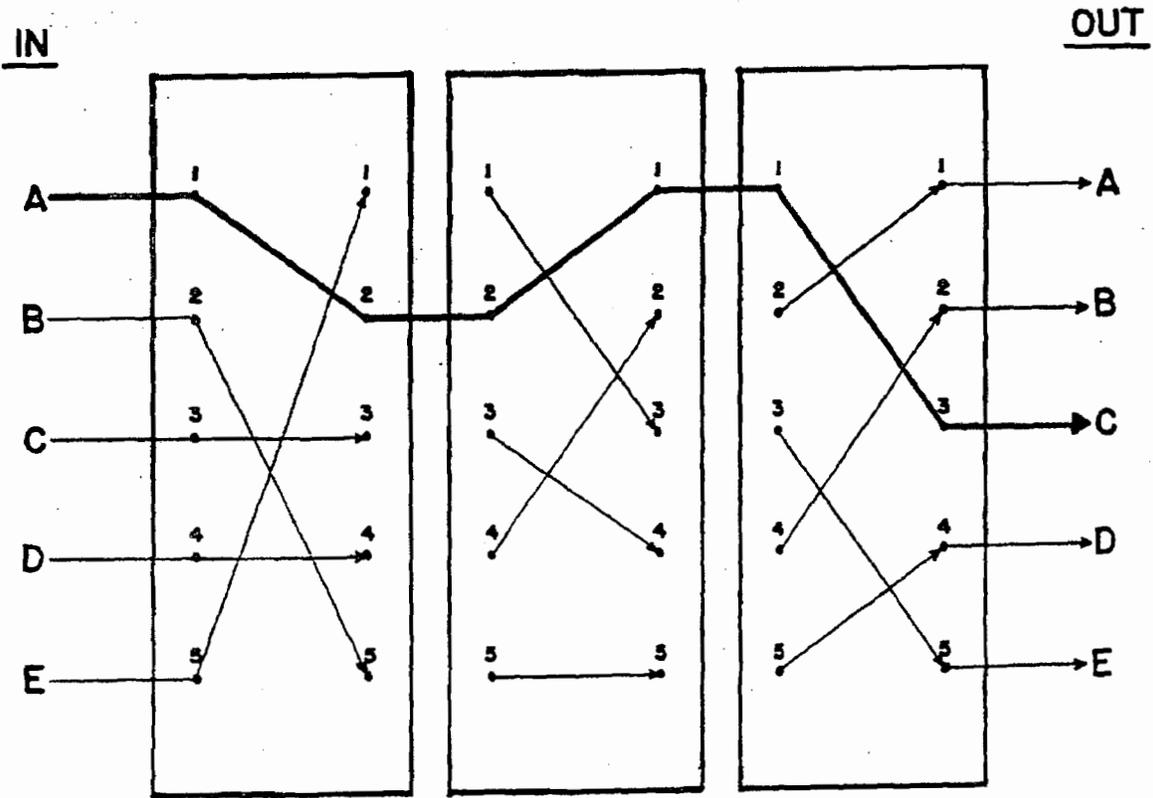
TSEC/KL-7 is the short title for the machine. The long or spelled out title is: "Electromechanical Literal Cipher Machine." TSEC is an abbreviation for Telecommunications Security which in turn is a full formal expansion of the term "Communications Security" or "COMSEC." There are only two important things you need remember about the signification of "TSEC"—one is that the item you see it attached to has something to do with securing U.S. communications; the other is that if it appears as the first designator of a short title, it refers to a whole machine; so TSEC/KL-7 is the whole hunk of hardware. If "TSEC" appears after some other characters in a short title, it means that the item referred to is only a component or part of a whole machine: so "KLB-7/TSEC" on the chassis, refers only to the base unit of this machine, less other removable components. The "K" in "KL-7" means, quite arbitrarily, that the item has to do with basic cryptographic processes, the actual conversion of something intelligible into encrypted form. If there were an "H" there instead, it would mean that the item merely facilitates the processing rather than actually doing it; the equipment is an ancillary or aid to the basic process, but does not do the encryption process itself. We have something, in fact, called the "HL-1" which permits direct decryption of text in teletypewriter rather than literal form with a KL-7.

The "L" stands for "literal" which I've already explained; all the machines which produce cipher text in the form of letters of the alphabet carry the designator "KL" unless they are merely ancillary, in which case they are called "HL." You'll find a brief run down of the scheme in KAG-1/T

There is one more thing about these short titles: in common usage around here, we tend to strip them down to their very nub, and we usually refer to this machine as the KL-7. We used to refer to it merely as "the 7" but now there's a KW-7 as well, so we can't do that any more. We have a rule in correspondence, by the way; that is that we use the full short title the first time we mention a machine, and may abbreviate references to it thereafter unless there's a possible ambiguity.

The KL-7 is probably the last major electromechanical cipher machine that will see extensive use in U.S. communications. There is a fancier, heavier, more expensive version of it called the KL-47 used almost exclusively by our Navy. I'll say no more about it except to let you know that it exists and is cryptographically identical with the KL-7—that is, they can intercommunicate (a sure sign of cryptographic compatibility). From mid-World War II until the mid-fifties, there were quite a number of cipher machines that would process literal text or teletypewriter text and used the principles from which the KL-7 evolved. They had a great variety of names and applications depending on whether they were built by the Army or Navy or the British, or by the Armed Forces Security Agency, NSA's predecessor. Cataloguing their names and trying to recall where and how these systems were used is a favorite pastime of the old-timers around here who like to reminisce. Most of them have by now been melted to scrap or are quietly corroding in about 2,000 fathoms of salt water. (The machine, not the old-timers.) The basic principle that they used involves electrical commutators called rotors to form a fabulous and ever-changing set of electrical paths—a labyrinth or maze—through which electrical pulses could flow.

SIMPLE THREE - ROTOR MAZE



5 - POINT ROTORS

The security of these systems derived from the fact that these rotors could be placed in any of a number of positions, and could be aligned and moved in many different ways. With some reasonable bank of these rotors, say 5, they could be set up each day, according to a key list in any of 5 arrangements, and rotated to any of 26⁴ starting positions; so that any one of millions and millions of starting points were possible, but only one would permit successful decryption. Of course, the people you were sending the message to would have to know what that starting position was. So, the sender would indicate this starting point to his addressee through the use of what we call an indicator system. A number of such systems for telling the distant end where you had chosen to start were contrived. Some of them involved a separate little device designed exclusively for that purpose; some used what amounted to a one-time pad which listed a series of starting points for each holder, but by the time KL-7 came along, it was clear that the only efficient indicator system had to make use of the KL-7 itself so that users were not burdened with two sets of materials to operate one machine.

The rotors are called "variables"; each contains random wiring that can be changed from time to time (but not very often). We keep the same wirings for from 1 to 3 years in KL-7 rotors sets. Because the security of the system is not greatly dependent on the frequent changes of the rotor wirings, we call them "secondary variables." The primary variables are the things changed each day according to the key list—these are changes in how each rotor is put together or assembled each day and which position in the maze each rotor takes.

The motion of the rotors is important to the security of any system of this type. Various rotors have to move in unpredictable fashion; and in fact, at least two and up to seven of the KL-7 rotors move after each individual letter is enciphered. If none of the rotors moved, but just sat there letter after letter, the old bugaboo, monoalphabetic substitution would result, for example, if "A" hit the path that came out "X" the first time, that same path would be there each subsequent time the A key was struck, and X would always result.

So a number of schemes were used to control the motion of various rotor machines. The most secret and high echelon rotor machine of World War II had enciphered motion with a whole bank of rotors in it whose only purpose was to move another maze through which encryption took place in a random fashion. Another scheme was to use a kind of clock or metering mechanism which would direct one rotor to move every time, another every 26 times, another every 676 times, another every time some other rotor did not move, and so forth.

In the case of the KL-7, notched motion was decided on. According to very complicated rules, the presence or absence of one of these notches on a given rotor will determine whether some other rotor or combination of rotors will move. It's not important for you to understand these schemes, except conceptually, in this particular course. I've dwelt on them because, later on when I cover the strengths and weaknesses of current systems, I'm going to have to refer back to this business of indicators, variables, and rotor motion in the KL-7, because they are involved in some attacks on this system of which we had little idea when we built the machine.

There are some more terms about the principles of the KL-7 with which you ought to be familiar because you are apt to run across them in discussing it and other similar systems. So far, I have described the principle merely as one involving rotors. The effect of these rotors is to provide a means for permuting plain language letters to cipher equivalents:

PLAIN	CIPHER
A	X
B	Q
C	E
D	J

With each setting of the rotors, we have generated a new substitution alphabet for all our possible plaintext letters; every plaintext letter has a different and unique cipher equivalent. This, conceptually, is what the cryptographers are talking about when they refer to alphabet generators, or to

permuting rotors, or a permuting maze. Since the maze is set up in a new configuration, i.e., the rotors step; with each letter enciphered, we have in effect a little *one-time* substitution alphabet for each process. I'm not going to go much deeper into the details of this system, even in this quasi-technical fashion. I suppose, though, I ought to point out how decipherment is performed. Simple. Turn a switch and the letters struck on the keyboard go through the maze backwards. If the receiver has started in the same place as the sender, he will have an identical initial maze, and his machine will step to successively identical mazes because his machine contains the same variables and their random motion is a controlled one governed by identical things—in the case of the KL-7, the particular patterns of notches and no-notches on the periphery of each rotor.

The KL-7 was introduced into widespread U.S. and NATO use in 1955. Today it seems a rather clumsy and obsolescent machine to us because of what we can now achieve through pure electronic computer-like techniques. There is a limit to how complicated and fast you can make a machine which depends on physical mechanical motion of a lot of parts for its essential activities. We may have approached that limit with the KL-7 and, I suspect, tried to exceed it with one of its contemporary machines, the KW-9 with which we tried, using rotors, to encrypt teletypewriter traffic at speeds up to 100 words a minute. So a good part of our early and continuing problems with the KL-7 were mechanical/maintenance problems keeping the stepping mechanism and printing mechanism in order; keeping the literally hundreds of electrical contacts clean—one pulse may have to travel through as many as 80 such contacts to effect the encipherment of a single letter.

But don't underrate this little machine. With all its troubles, it is still passing thousands of groups of live operational traffic daily. Its resistance to cryptanalysis remains very high and its useful life will reach well into the 70's. It remains, in my judgment, the best literal cipher machine in the world and we and NATO now have something like 21,000 of them.

Let me touch on some of its advertised features. It was our first machine designed to serve very large nets which could stand matched plain and cipher text. For the first time, the man in the cryptocenter could take a message and simply type it into the machine as written, without changing the spacing between words, or cutting the message in half and sending the last part first, and without having to paraphrase the message text before it was released. It was the first machine in which transmission of the indicator was a straightforward matter of sending out the letters lined upon the machine in the clear (a procedure which we abandoned about 1962 in the face of advancing cryptanalysis). It was the first relatively lightweight and secure electrical cipher machine with a keyboard—relatively light; by that I mean around 30 pounds, vs. about 90 pounds for its predecessors. It was the first equipment that could run off a jeep battery as well as 110 or 220 volt power. It was the first equipment that could encrypt both digits and letters without a clumsy adaptor—I ought to point out to you though, that the equipment turned out to be overdesigned in that respect. Numbers are so critical in typical military texts that the garble of any digit in them may cause real havoc—so, almost always, numbers are spelled out rather than put in upper case by KL-7 operators. It was the first machine designed to permit the ready removal of the classified components for secure storage so the whole thing did not need guarding or chucking in a safe. Finally, the rotors designed for it were the first that could be easily rewired by manually plugging their connections to new positions. All previous rotors had fixed, soldered wires so that changing their patterns was a slower and most costly process.

In 1966 we had about 25,000 of these KL-7 machines. Where were they used and for what? As some of you may know, we keep fairly careful records on the usage of most of our systems: each user provides a monthly Encrypted Traffic Report (or ETR in our jargon) in which he lists the number, length, and classification of messages transmitted. In the case of the KL-7, we found that the highest use was in U.S. Navy networks, next Army, and last Air Force.

It is quite apparent that large numbers of these equipments are rarely used; they are held in reserve, for privacy or as back-up for more efficient on-line teletypewriter equipments in most of the centers where teletypewriter service is available. Networks employing KL-7's range in size from 2 to 2,188 holders; a feature which perhaps I have not sufficiently stressed. Until quite recently, there

~~SECRET NOFORN~~

were very few machine systems which had the capacity to accommodate a thousand or more holders all using the same key; all intercommunicating without having to use unique sets of variables.

Before we leave the KL-7, let me give you another fragment of the nomenclature picture—that's the use of designators selected from mythology. You heard me use names like COMUS and DIANA to identify some of the manual systems we covered earlier. Some of the machine systems have these names—usually Greek—as well. The KL-7 system is called ADONIS. So is the cryptographically identical system produced by the KL-47. What these designators amount to are convenient means for identifying a specific encryption process regardless of the particular machine doing it. In the decade of the 50's, this method of identifying a cryptographic process was quite useful to us, because typically, two or three or four quite different-looking machines could all be made to operate identically; and further, each of them might be able to accomplish several quite different basic encryption processes by the change of some components or switches or procedures. So rather than saying "the system produced by the KL-7 or KL-47 using a 12-rotor set and encrypted indicators," we can say, simply, "the ADONIS system:" the same machines, but using only 8 rotors and indicators sent in the clear we called POLLUX.

These names are superfluous when only a single kind of equipment exists to do a job and that equipment accomplishes only one basic encryption process. Some of the new systems either don't have Greek names at all, or you rarely hear them; instead, we just specify the hardware by short title.

00 ~~SECRET~~

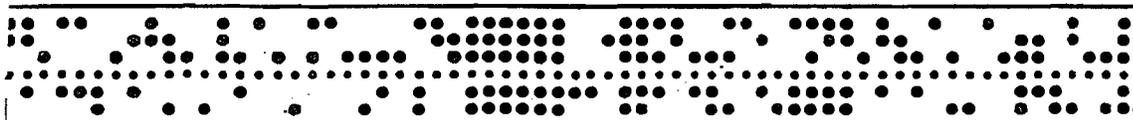
ORIGINAL

FOURTH LECTURE: One-Time Tape Systems

So far in these lectures, all of the systems I've mentioned have had one thing in common. They have widely differed in structure, process, security and application; the thing that has been the same about them is their relation to the communications process. They are all *off line* which means, once again, that they work essentially independently of the communications set-up; they are not tied into the communications path; the complete encryption process is performed *before* the cipher text is transmitted, and the nature of the communications system to be selected for the eventual transmission is not of much consequence.

From now on, with a few exceptions, the systems we will be talking about will be more and more involved with specific means of transmission; most of them will be on-line systems or systems with both an on-line and an off-line capability. This means that the machines themselves, or the ancillary equipments used with them will be more and more tailored to particular communications techniques and eventually, as you'll see, will involve the *integration* of the cryptographic process into the communication system itself.

The first and simplest set of systems lashed into their associated transmission means are the one-time tape systems. They are called the PYTHON systems for fairly obvious reasons. From World War II until about 1960, these systems were very popular indeed, and are still rather widely used. In both WW II and the Korean War they formed the backbone of secure U.S. teletypewriter communications. I can name more than 12 different machines built since 1945 for PYTHON operations. Their principle is deceptively simple, you merely take a stream of random key in *binary form* and *add it—combine it, mix it—element by element*, with plain text that has also been produced in *binary form*. To put intelligence into binary form is to convert it (or, in the generic sense, *code it*) into symbols made up of only *two* elements—1's and 0's—the familiar computer language; or pluses and minuses, or on's and off's, or marks and spaces or, as on tape, holes or no holes as indicated in the following illustration:



Various teletypewriter equipments automatically convert characters into this binary form. for example, in the Baudot teletypewriter code:

A = + + - - - ; R = - - + - - , etc.

The additive or mixing process is done according to a simple, arbitrary rule: like signs = plus; unlike signs = minus. Now, let's add:

PLAIN TEXT	-----	+ - - -	- + - + -
RANDOM KEY	-----	- + + - -	+ + - - -
<hr/>			
RESULT (CIPHER TEXT!)	-----	- - - + +	- + + - +

It turns out, that if you take the same key and add it in the same way to the cipher text, the resultant product is the plain text again—and thus you decipher. If you can find a way to do this mixing mechanically, or electrically or electronically, you can visualize an extremely simple set-up. Your send and receive machines are identical and use identical key tapes in identical ways.

You do not have to reverse your process, switching everything so it goes backwards as we did in the rotor machine. The receiver merely assures that he is using the same tape as the sender, and has started it in the same place, and by adding it to the cipher text he has received, gets a copy of the original plain text printed automatically for him by the teletypewriter equipment.

Like all other one-time systems, though, the key must be used once and only once for encryption; if it's good random key and is used properly, the cryptographic security seems to be absolute. If you use the same key twice for encryption, the security drops to approximately 0, forthwith.

I said I could name about a dozen of the machines. The reason for the variety stems from two causes: first, the adaptation of machines to more and more refined concepts of teletypewriter communication; second, the need to prevent compromising radiation—the electronic emission of intelligence in the form of radio frequency energy from the various switches and contacts and relays in the equipment. We'll talk about *that* problem at some length in the last lectures.

The simplest kind of teletypewriter transmission path is a line from point A to point B with transmissions travelling in one direction only. This is called a *simplex circuit*. There are some obvious disadvantages: B can't talk back. A much more common type of circuit is a path between A and B on which either station can send when the other is silent. This is called a *half-duplex circuit*. Still some disadvantages: they both can't send at once—something communicators like to do, especially if each has a high volume of traffic for the other. The optimum setup permits transmission to flow in both directions simultaneously and is called a *full-duplex circuit*. Such circuits really involve two separate radio paths or two pairs of wire lines, but some of the terminal equipment may be shared. Different kinds of one-time tape crypto-equipment were envolved to fit with these differing communications setups.

The simplest way to send teletypewriter characters over the paths is by what is called "Start-stop" operation. The receiving machine *waits* until it receives a character, deciphers it, moves its one-time tape one position, and waits for another character before operating again. So it keeps in step with the sending machine by using each actual cipher character received as a signal to advance. Most of the old one-time tape mixers worked this way. But suppose the transmission fades momentarily, and the receiving machine misses just one character: or suppose some spurious pulse hits the signal line and causes the receive machine to advance when no cipher character was really sent? Then the two machines are out of step—synchrony between send and receive tapes is lost, the keys no longer match, and thereafter the receiver deciphers gibberish until the operator can signal the other station to stop and they get themselves in step again. So they began to design machines which would step along at a fixed rate once they got started together, whether every character was received or not, and the short transmission fades or spurious pulses simply caused a one-letter garble in the received text. These are called *synchronous machines*, and account for two or three more of the dozen mixers that have been in our inventory.

Yet another feature became desirable for some one-time tape circuits. You will recall that I have mentioned the term Transmission Security or "TRANSEC" just once so far. We were discussing a manual one-time system and I alleged some COMSEC shortcomings despite its great resistance to cryptanalysis. The bread and butter of *transmission security* specialists is the information that they can glean merely from analyzing message *externals* as they are transmitted. Call signs tell them something, so do routing indicators, so do cryptographic indicators, so do the numbers and lengths and formats of messages, so does the direction in which traffic flows. If the government is planning a secret operation in some remote or not so remote place, there is almost bound to be a great spurt of message activity to and from that place, and all the opposition need do is note this surge of communications activity to be put on guard. The technique which we now commonly use on teletypewriter links to remove most of these flags on impending activity is called *traffic flow security*. In a one-time tape setup, the way it is accomplished is to simply send cipher text or something that looks exactly like cipher text *all the time*. Instead of cipher characters being transmitted by fits and starts only when an operator is actually typing a real message, or where a few hundred groups are coming out in a stream if the operator is sending his message automatically on a previously punched message tape, the machine is rigged so that whenever an actual mes-

sage is not being sent, the successive characters of random data on the key tape itself are automatically sent instead. So the roll of tape just sits there and unwinds all day, encrypting anything you happen to have for it and being transmitted itself otherwise. The tape on the other end is doing the same thing, of course. All the interceptor sees is an apparently continuous flow of random information. What does the receiver see? Since his tape machine tries to decrypt anything it receives, it winds up decrypting *key* when no bona fide traffic is coming in. Let's have a look at what any one-time key decrypted (i.e., added to itself) looks like. Remember our rule—like signs = plus; unlike's = minus.

++--+++++--++++--
++--+++++--++++--

+++++ . . . All pluses!

And all pluses equate to the letters shift character in the Baudot code, and it's a relatively simple matter to instruct the teletypewriter to stop operating until it gets something else. Otherwise, you can just let it run. So, equipments with this traffic flow security feature account for a couple of more of our many PYTHON machines.

Well, let's have a look at the advantages and disadvantages of these PYTHON systems. The first advantage is relatively great speed compared to any of the systems we have described so far. In most of the manual systems you feel like a whiz if you can average four or five words a minute: in our off-line rotor machines, we were happy with 25 words a minute and simply couldn't go much more than 40. But a PYTHON system operates at standard teletypewriter speeds—66 or 75 or 100 words a minute. And besides, when you're *on-line*, the message is being received instantaneously at the distant end: so with PYTHON we are moving toward the goal of secure communications in which no delay in message delivery can be attributed to the cipher process itself. You're still consuming a little time in pure cryptographic processes—you have to select and set up the proper tape; you have to send an indicator of "Set" to the distant station to tell him what tape to use and where to start it; but most of the time is spent in preparing the message for transmission—punching it up on a message tape ("poking" they call it) before feeding it into the machine—this is something you have to do anyhow for efficient teletypewriter communications in any volume. So, on the matter of speed, we have made a great leap forward.

The second advantage is its relative simplicity: most of the system consists of standard time-tested teletypewriter machine components which are commercially available; maintenance is relatively easy; teaching an operator to work the system is simple; mistakes are hard to make and only one mistake—the reuse of a tape—is dangerous to the security of the system. (In contrast, on a system like KL-7, there are a dozen or more things that operators can and do do wrong which give us grey hairs.) There are other things that can go wrong of course; technical things, like the tape getting torn and failing to feed properly and the machine going merrily on encrypting all of the message using whatever key character the tape happened to stick at—monoalphabetic substitution again! But there are a number of safeguards built in for contingencies like these, and by and large it is safe to say that a typical one-time tape system is both reliable and highly secure.

So, the advantages, in summary are: fast, simple, reliable, and secure. How about the disadvantages? By now, the first disadvantage ought to leap readily to mind. They are one-time systems, and the inherent disadvantage in all of them applies here. Only two or a few more holders can intercommunicate in a given system—we make a few "five way" tapes and "ten-way" tapes to accommodate some broadcast or conference type teletypewriter communications; but it's a difficult job to get everybody in step and keep them there, and by and large the two-holder or "point-to-point" system prevails.

The second disadvantage is a logistic one: imagine the complexity of the distribution system that gets thousands of pairs of these tapes out, to holders all over the world. Their bulk, in a large communication center in which many tape systems terminate, is staggering. In their heyday

660,000 rolls of tape were produced by us in 1955. Production is around 55,000 now. The consumption of these tapes is particularly distressing when that transmission security feature—traffic flow security—is employed. One of these eight-inch 100,000 character rolls lasts about 166 minutes at 100 words per minute; they cost us \$4.55 each.

At any rate, their usage has begun to decline sharply as more efficient means for doing the same job have evolved. As early as 1942, the people designing cryptomachines had tried to come to grips with the logistic problem associated with one-time tapes. All the one-time tapes used by the U.S. come right out of Operations Building #3 in what is called a tape-factory. Great batteries of tape generation equipment, which will be described to you later in the lectures on the production process, can spew these tapes out at the rate of thousands of three-inch rolls per day. In the old days, the manufacture of these tapes was slower. Very large machines were used to produce carefully checked random data to be punched into the tapes. "Suppose," said the cryptographers, "you could build a machine that could generate its own key as it went along and feed that key to a mixing or combining circuit electrically without having to punch it up in a painstaking mechanical fashion on a stretch of tape? Give the man at each end of the circuit a key generating machine which, from given starting setups, would produce identical key that could be used in this same old binary additive mixing process that works so well with the one-time tape systems. Then, instead of having to distribute carloads of tapes to these people, we would merely need send them a little printed key list containing the settings that should be used for the variables contained in the little key-generating machines."

And that's what they did. They called the equipment SIGTOT in accordance with some old Army Signal Corps nomenclature scheme. It used rotors, and it worked pretty well. Its key output fed into a standard one-time tape mixing machine and got combined there in the regular old way. But it used rotors with all their mechanical difficulties, and we found ourselves shipping around truckloads of rotors instead of carloads of tape. When you see the tape factory, you'll note that a rather massive batch of machinery with all sorts of checks and alarms are used to assure a completely random output. When you try to compress essentially the same operation into equipment about as big as a headbox, you might expect troubles, and we had them. We wound up with all sorts of procedural constraints on the use of these systems for security reasons, and eventually had to use a set of no less than 30 rotors to support each machine so as to provide an adequate bank of variables to choose from. Still, the SIGTOT, with various modifications, lumbered on in some quantity from WW II until the mid-fifties and the last ones did not disappear until about 1960.

So far, we've confined ourselves pretty much to how these various systems work, what they can do, and what they are for. Before we jump into the electronic age of cryptography, perhaps it would be well to discuss some of the things that go into the production and support of a cryptosystem beyond the provision of sound cryptoprinciples and some techniques for making them work—by embodying them in pads or charts or tables or in some kind of cipher machine. Implicit in what I've said already, you have to have somebody design and develop these systems and, in the case of hardware, that's what NSA's R&D COMSEC organization is for. You have to have somebody evaluate these designs; and it seems sound practice to have a body of people who are separate, objective, disinterested, do this job—not the inventors themselves who are apt to have prejudices and blind spots with respect to their own brainchildren; and that's what our COMSEC analysts are for. You have to have somebody who can take these approved designs and prototype equipments and engineer them into fully tested working systems that can be produced efficiently and in quantity—to make a finished product which, in addition to being theoretically secure will be economical, reliable, and practical to produce and maintain. That's what the COMSEC Office of Communications Security Engineering (S2) is for. There are still more things you need. You have to have an organization to produce and distribute these volumes of variables on which every one of these systems in one way or another depends. That's what the Office of Communications Security Production and Control (S3) is for, and, of course, you need instructions. You need the specific operating instructions that tell operators just what to do, what processes to follow, how to react if something goes wrong; you need systems planners to anticipate and meet requirements and to get

the right equipment applied to the right job. You need a very involved and interlocking set of security controls over the materials and equipments in the inventory—you need to decide how to mark, classify, ship, store, account for, and eventually destroy every item. You need a whole system of surveillance to watch over systems as actually used to assure that they meet their security objectives and, where they don't because something has been lost or some other catastrophe occurs, to implement, and implement at once, whatever countermeasures—like the emergency supersession I talked about—that can be put into effect. This means a world-wide reporting system to inform us electrically of events that may effect our COMSEC posture, and a large quantity of back-up or reserve materials for use in an emergency. During FY-72, the Office of Communications Security Applications (S4) was established to better support the systems approach to COMSEC. This organization consolidates and emphasizes the S effort towards the system approach, wherein security is functionally and physically intergrated into communications-electronics systems of all types. It insures a consistent and coordinated effort in meeting NSA's responsibilities to system designers, developers and users for providing COMSEC support and provides a focal point within S for outside organizations to turn to in seeking assistance in systems matters. And finally one of the most difficult jobs of all—you need a large, consistent, coherent, practical, responsive, safe, reasonable, and understandable body of *doctrine* to govern the whole shooting match, and this is what the Office of Communications Security Standards and Evaluations (S1) and the Technical and Planning Staffs are for. And these are all more or less central functions here in NSA; large counterpart organizations, especially in day-to-day monitoring and administration of systems, are required among the users. For what we are talking about here is the management of a very large operation—not only are millions of copies of paper materials involved, but we are supporting on the order of 100,000 relatively delicate, undoubtedly contrary, tricky, recalcitrant, *classified* cipher machines.

Perhaps you did not realize it, but what I've just done is sneaked in on you a rundown of the functional organization of the COMSEC part of this Agency.

I have implied that the business of protection and control of cryptomaterials constitutes a large and difficult area of endeavor for us. While one-time tape machines are fresh in your mind. I want to discuss classification for a moment, because there is a small controversy about the classification of these equipments and it is illustrative of the kinds of control problems we encounter.

25X3, E.O.13526

25X3, E.O.13526

The second reason is clearly a COMSEC one. Even our newest one-time tape mixer is not perfectly secure. I keep titillating you with this business of compromising emanations; we want to keep other people from discovering the techniques we use to suppress these emanations; and we also want to make it difficult for them to find out where we have still been unsuccessful. It turns out that the ideal way to exploit the radio frequency or acoustic emissions from a cipher equipment is to get the thing in a laboratory and test it very thoroughly and minutely to find out in what part of the spectrum, if any—the emissions are escaping and just what their characteristics are. Having done this, you know how to zero in your intercept equipment in the much more difficult environment where machines are actually operating, and your chance of success is much greater than if you have to go at it blind.

There is another related and long-standing notion about classification of crypto-equipment that is worth discussion here. It involves a rather difficult concept, more often misunderstood than not, and one that often causes much anguish among our customers each time it leaks out in distorted or incomplete form. Here it is: whether we're talking about a one-time tape machine, or the KL-7, or a modern key generator system, the essential security lies in the variables supplied with the equipment, *not* in the configuration of the equipment itself—not in its wiring, motion, activity, or processes. This means that if the machine is lost, no past or future messages encrypted by it will be jeopardized unless its variables—its *keys* are lost as well. There's a very practical reason for designing systems this way: no matter how highly we classify an equipment or how carefully we guard it, we cannot *guarantee* that it will not be lost. All of them are designed to be useful for 15 to 20 years and a lot of things can happen in that time—military units can get overrun; planes can crash in hostile territory; people can defect. We simply can't afford to replace 10,000 key generators or 25,000 KL-7's should that happen.

So, in a nutshell, if you lose the equipment, but not the keying material, your traffic is still secure. When the customer hears this, he has a natural question: why in the world do we insist on classifying these machines then? And he has more than an academic interest: the protection of these machines costs him money and time and guards and vaults and specially constructed cryptocenters and a host of attendant headaches.

Well, why do we insist that this expense to the user—and it's a real expense—is a worthwhile security investment? I have already touched on the matter of general exposure of our technology. But there are even more cogent reasons for trying to protect principles and details of machine operation *when we can*. The first is this: although we strive for reliability, and sometimes can afford to incorporate rather elaborate alarms, machines do sometimes fail or partially fail. In the case of a modern high-speed key generator, thousands or millions of bits of faulty key or cipher text may be put on the air before the problem is detected and the machine halted. There may be even more insidious failures that do not affect communicators' ability to encipher and decipher messages, but seriously weaken the resistance of the system to analysis. The discovery of exploitability of such situations by hostile interceptors may well depend on whether he understands the fundamental structure of the machine in use; so denying him that information to the extent we can is important. Similarly, operators may make mistakes that may be harmless if the interceptor does not understand the system, and exploitable otherwise. Note, the basic proposition is still that the traffic is secure with the machine known, but with the keys safe. We have to modify that statement to indicate that this is so except in cases where the machine is operating improperly—and sometimes they do operate improperly. And we have said, there's not much problem so long as the keys are safe. The trouble is we *do* lose keys (in FY-72 there were 325 incidents of loss and unauthorized viewing). But a stolen key will generally not do the hostile analyst much good unless he knows how the machine works that uses it. Finally, the most important reason for protecting machines is that a hostile cryptanalyst generally cannot even make a start on the analysis of any cryptosystem until he has been able to discover in some detail what the basic processes of encryption are. This is borne out by the very considerable investments our own SIGINT organization has made simply to find out target systems work; it's a prerequisite to any subsequent analysis.

FIFTH LECTURE:

KW-26; KW-37; CRIB; KW-7

Now, after that small excursion into the realm of doctrinal, organization, and classification matters, let's return to hardware. First, I'll bring you up to the present with respect to teletypewriter security equipment. By the mid-fifties, computer technology was fairly far advanced: the impact of this technology on cryptography has been enormous in two respects. In the first place, for all but the one-time machines, security rests on the fact that we provide a very large but *finite* number of variables: we confront the hostile analyst with a system which can be set up in any one of millions or billions of ways so that "guess factor" in a machine instead of being something like 1 in 26 in our weakest authentication systems, is 1 in many billions. So, in a straightforward cryptanalytic attack, what he may want to do is to try out every one of the possible settings in the system, matching each trial with intercepted cipher text and when he hits the right setting, plain text results and he has recovered the day's setup. In the old days with weak systems, analysts might try to do this by hand, making a few hundred guesses or trials a day; later punched card equipment and other electromechanical equipment were used so that 10's of thousands of trials might be practical. But, *with computers*, our analysts and the opposition found a tool that would permit *1,000's or millions of these trials to be made each second*. The result was, that in cryptosystem design, enough variability had to be assured to resist postulated computer attacks of enormous power; perhaps entailing a hundred or more computers operating simultaneously against one system at speeds of 10^4 seconds for years on end!

At the same time, computers provide a practical technology for translating pretty well known mathematical techniques for producing very long unpredictable streams of data into electronic hardware. Such machines could be constructed to accommodate a barrelful of variables; a completely new set of variables could be inserted ("programmed") simply by use of an IBM or Rem-Rand punched card; the circuitry was ideal for performing the usual binary addition to the random data—that is the key stream—with plain text presented to it in digital form. So the notion of a cipher machine which was really a self-contained *key generator*, which had its clumsy beginnings with the SIGTOT rotor machine, came into its own with the computer age and, in 1957 we began delivering the first of about 15,000 TSEC/KW-26 machines for the rapid, secure, on-line synchronous transmission of teletypewriter traffic. Out went the SIGTOT's (by this time having undergone their fourth major security modification and umpteenth procedural change); out went most of the one-time tape machines on high-level TTY links. The KW-26 system turned out to be a jewel. I have heard some Service cryptographers who had been skeptical of the role of this centralized Agency say that this system, the TSEC/KW-26, more than any other, made the reputation of NSA and solidified its position as the authority in cryptographic matters.

The advantages of the system over its predecessors really are manifold. It has no moving parts, and its speed is limited only by the speed of the associated teletypewriter equipment. One three-cent punched card for the daily setup replaced about \$20.00 worth of tapes. It could be programmed to operate in a variety of communications modes; it is designed for rack-mounting and was the first major crypto-equipment built to be part of the *communications center* rather than being cloistered in a dark vault-type corner—that aloof, separated *cryptocenter* of the old days.

The cryptoprinciple was based on the mathematical discovery of an Italian name Fibonacci (1170-1248) who is alleged to have contemplated sunflowers and noticed that the number of seeds progressing from the center of the periphery of the flower forms a very peculiar, irregular, and apparently unpredictable numerical sequence. (All this sounds like Newton's apple, and may or may not be apocryphal.)

There's one more thing about the principle of the KW-26 I ought to mention. When we use a one-time tape or a one-time pad to provide key, and add our plain text to it, we use every element of the key: I've said a couple of times that, should you use such key more than once, all security is lost. When two ciphertext messages are based on the same key, the messages are said to be "in

depth"; and the thing that provides the analyst a means for successful attack is the fact that the identical element of key underlies two different cipher characters. To frustrate this kind of an attack on the KW-26, the designers made it so that it produces 32 times as much key as it needs: only one key element out of each thirty-two is used; the rest are thrown away. So should something go wrong with the machine, or should somebody use the same key card twice (and that's hard to do because the card gets automatically cut in half with a knife any time you try to remove it from the machine), only one character in thirty-two is "in depth", and that's not enough for successful cryptanalysis.

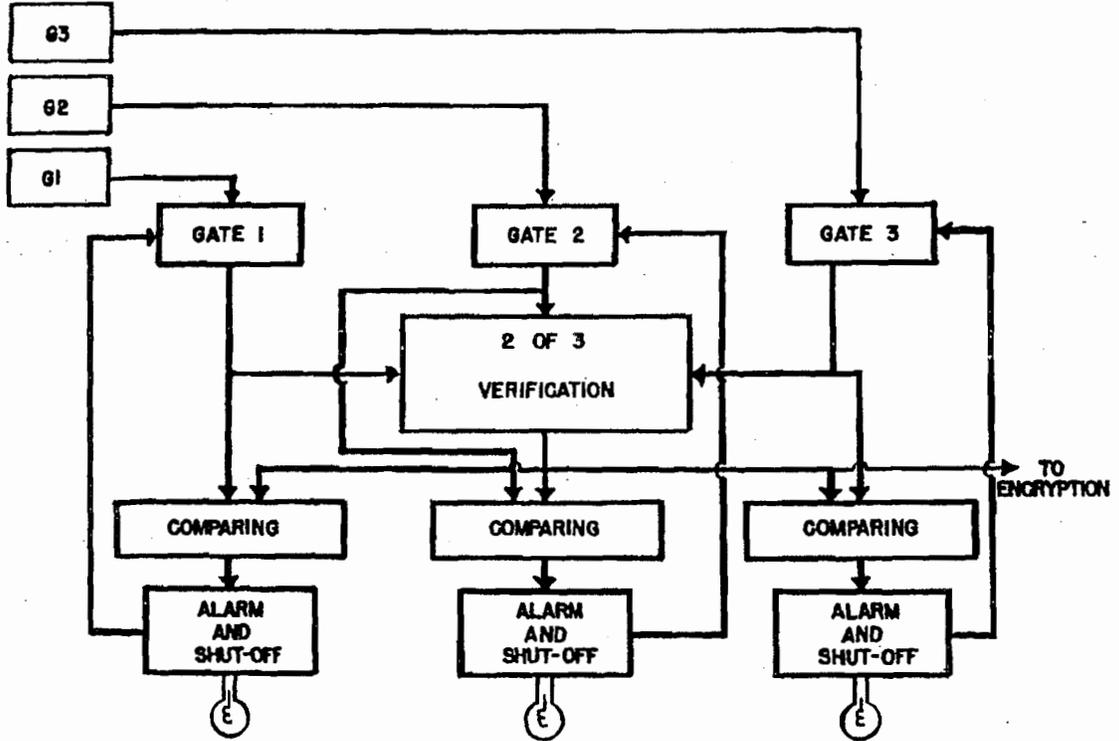
But the KW-26 can't do everything. It is essentially a point-to-point system, and you need a great battery of them when you have to communicate with a lot of different stations. In March 1973 here at Fort Meade, where the CRITICOMM system terminates, we had 336 KW-26's lined up and operating all the time. We have some tricks so that a single KW-26 can be used to send to a number of receiving stations at once, but the scheme is not very efficient and I know of only one net employing it.

We do have a requirement for broadcast of secure teletypewriter communications, with a few central stations sending out information and instructions to a large number of receiving stations simultaneously. The Navy is the principal user of such systems to notify all the ships at sea of ship movements, weather, general information, instructions to the fleet, etc. The system we have provided for this is called KW-37. The "W", by the way, stands for "teletypewriter", just as it does in the KW-26. The specifications for this system were pretty tough. Not only did the Navy want to be able to reach 100's of receivers simultaneously; they wanted each of those receivers to be able to tune in at any time in the day and, knowing only what the day's key card was, be able to begin decipherment even though the transmitting machine had already been running for hours. You'll recall that in every other machine we've talked about so far, this business of getting machines in step and keeping them there was crucial; and we accomplished it by sending out an *indicator* and, when we were on-line, starting off both machines at essentially the same time. Now we had to find a way to allow some laggard receiver to "catch up" with the sending machine, starting blind, and with no way to communicate with the transmitter to ask him where he was. It wasn't done with mirrors—it was done with *clocks*. The transmitter always gets going at the same time; say 8:00 A.M. Greenwich or "Z" time; the receiver sets his clock close to the actual time when he wants to get into the net—say noon—and then starts his receiver key generator at its initial (8 A.M.) setting and flips a switch that causes it to generate at 570 times its normal speed until it *catches* the transmitter. As it approaches the setting of the transmitting key generator, that is, approaches synchrony with it, it looks at special timing signals coming in from the transmitter, locks on them, and then reverts to normal speed and is able to decipher the incoming traffic thereafter. The time it takes to do this is from a few seconds to a maximum of 2 minutes, depending on how far behind the receiver is when the process is begun.

There is yet another difficult requirement associated with broadcast operations: that is that the transmitting equipment must be ultra-reliable. Once it gets going, it can't afford to stop. There are both security and operational reasons for this. In ordinary on-line TTY operations, obvious faults in the transmitting machine are immediately detected by receiving stations because garbled traffic is produced. The receiving station can stop or "BREAK" the sending station before much damage is done and have it straightened out. But without a ready return communication path, as in the case of KW-37 networks, a faulty transmitter might send gibberish to the fleet all day. From the operational viewpoint, even if he does detect it, perhaps by a monitor of his own broadcast, he can't stop transmitting or, rather, when he does, can't get started again because the clocks are all thrown off.

How did they solve this one? I believe I mentioned in passing that most of our modern systems have various alarms in them to detect possible failures. In the KW-37, the concept of alarms has reached, possibly, its ultimate. Instead of using a single key generator in the transmitter, we use three identical ones which, each day, are set up with three identical key cards. They are so interconnected that the output of each key generator is compared digit by digit with the outputs of the other two generators as indicated in the following diagram:

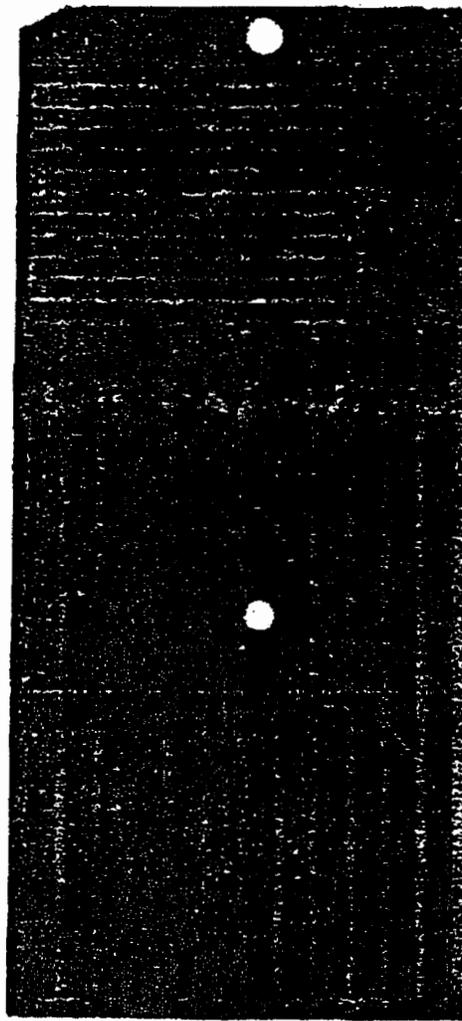
KW-37 VERIFICATION AND ALARM CIRCUITRY - SIMPLIFIED



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If all three put out identical key, we know that either they are all operating exactly as they should or that all three have somehow developed some identical fault. We assume the former situation is the case, and begin transmitting. Now, after operation has begun, if one of the generators develops a fault, its key stream will no longer match the other two: the machine operating on a "majority vote" principle assumes that the two matching keys are correct and continues to operate using one of those keys. But lights light and bells ring on the faulty key generator; the maintenance man can pull it out of the rack, fix it or replace it while the machine carries on so long as the outputs of the two remaining key generators continue to match. Foolproof? We thought it was nearly so. But to show you how far out this business can get, and how careful you have to be; and to illustrate "Murphy's law" which says that anything that can possibly go wrong sooner or later will, let me tell you what happened during some of the early Navy testing. The main components of the KW-37—as in most of our modern electronic equipments—are printed circuit boards containing relays and transistors and shift registers and combining circuits and the like. About 80 of these boards go into the makeup of each of the KW-37 key generators. Routinely, during maintenance, some of these boards are removed. The Navy discovered that there were some boards in the KW-37 which could be removed without stopping the machine. But the generator would put out faulty key. They put two key generators into operation with the same boards missing and used a faultless key generator as the third one. Sure enough, the machine went through its majority vote process and, because the two keys from the generators with missing boards matched exactly, the machine used their key and rang bells and lit lights saying the only good generator was bad. So the system had to be modified to include interlocks so it would not work with missing boards. The KW-37 happened to be a Koken, not a Fibonacci: the overall process of key generation is quite similar, but the specific rules of motion for producing successive bits of key are different.

At this point, I ought to mention the CRIB (Card Reader Insert Board), presently in use in the KW-37, certain KG-13 nets, and planned for use on several other keycard equipments.



The CRIB is in fact a circuit plate to be mounted in the card reader as a replacement for the circuit plate originally supplied; there it serves as a second keying variable. If the original circuit plate is thought of as one that is "straight wired", then the CRIB can be considered as one in which wiring is "scrambled", for it establishes a different set of interconnections. We issue the CRIB in various editions. Each has a different short title (USKAW-1G/TSEC, USKAW-2F/TSEC, etc.), and each is effective for a specific time period. The conductive paths provided by each edition differ from those of other editions. Two equipments equipped with CRIBS are able to communicate only if both use the same key card and have the same edition of the CRIB installed in their card readers.

So far, the modern machines I've talked about have retained some of the inflexibilities inherent in this business of using a single long stream of key and using it only once—only a few people can *intercommunicate*. Normally two in the case of KW-26; and only one sending and a lot of people listening in the KW-37. What was needed was a new principle or an adaptation of the old one which would permit a large number of people to *initiate* transmissions all using the same key list, or plug board or punched key card or what-have-you. Remember, we had this capability with some of the rotor machines like the KL-7. The way we did it was by sending out some random information—an *indicator*—with each message. This indicator started us in one of millions of possible alignments

thin the basic setup of the machine for that day. We needed something analogous in the electronic key generators because it is through this process that you can generate millions of unique streams of key from some basic settings of the machine.

Remember that the Fibonacci principle in the KW-26 was predicated on an initial sequence of random 1's and 0's. The day's punched key card could supply that sequence. Now, if with each message something unique and random was added to it, then we had the basis for generating many key streams—one for each message—and a way, therefore, for many holders to originate messages using the same basic plugging or key card setup. The first equipments using this idea happened to be for voice encryption, but the idea is the same, and it is now used in the brand new tactical teletypewriter security device called the KW-7. A device called a *randomizer* is provided within each equipment; it uses some unstable or "noisy" diodes that emit electrons in a random fashion; these are converted to digits (1's and 0's again) fed into the transmitting machine and, at the same time sent out to the receiving machine. The effect of this random stream is to alter the day's setup in an unpredictable way, but in the same way in every machine receiving it. Thereafter, the equipment operates like a normal key generator until the message is finished. When it is, and another message is to be sent, the "Start" buttons is pushed again; a new random stream is provided by the randomizer, and the equipment again operates, but on a new key.

We have more or less backed into the subject of the KW-7 and so far your conception of it must be rather hazy: I've said it's tactical, and that a lot of people can intercommunicate with it because it uses a randomizer to alter the basic key for each message. Also, it is not set up with a punched card. Why not? Because the user decided he didn't like key cards, and wanted a way to set up the machine from some information printed on a piece of paper. We're not sure the user was right about this; and evidently, he's no longer sure either because he is now asking for us to modify some of them to accommodate setup by punched card.

It will be useful to know something about how requirements arise—why new machines are built—and how we go about it. The user buys these machines from us although we pay for the research and development work ourselves. The chain of events usually goes something like this: One of the three Services decides it needs a new crypto-equipment—say, a tactical teletypewriter equipment. He'll decide this because their existing equipment is obsolescent: too heavy, or too slow, or too expensive, or incompatible with new communications techniques, or this Agency has said its security is becoming marginal, or something. They will then describe what they want in terms of its size, speed, power requirements, amount of security needed, and the like. They will then consult the other Services to get an expression of interest. If the other Services think they also need the same thing or something similar, they may get together and write what are called Joint MC's—or military characteristics. They will send these MC's to NSA and either ask NSA to build such an equipment, or ask that NSA delegate the authority to one of them to develop the equipment. Usually, NSA winds up doing it. Then that functional organization I described to you takes over—R&D decides on a cryptoprinciple to meet the security needs, the intercommunication requirements, the speed and volume of traffic specified, and the kind of communications to be used. S1 evaluates the principle and, having given it the go ahead, R&D develops hardware, usually starting with hand-made "breadboard" models in their own laboratories and finishing with a full development contract in industry. S2 tests the development model, arranges for Service Test models to be made—if it seems good enough—or arranges for service testing of the development model to save time; the Services state what they do and don't like about it, and what they want changed, and production models incorporating these changes are made. This whole process can be as fast as 18 months from conception to hardware as was the startling case of the great KW-26, to many years as in the frustrating case of some of our tactical voice security equipment. Meantime, systems planners and policy makers are not sitting idle; they are looking for optimum applications; establishing programs for phasing out older equipment, deciding whether other requirements can be fulfilled with the oncoming hardware—does NATO need it? Is it in the best interest of the U.S. to release it to NATO? Whether they need it or not? And so forth.

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So, the KW-7 followed that general process. It has features in it to satisfy special needs of each of the Services, e.g., adaptors It was offered to NATO in competition with some comparable equipment being built by the UK, France, Germany, and Norway. It can provide for secure communications among hundreds of holders all using a common key; it's mounted in some aircraft and on wheeled vehicles, and we expect to see 38,000 in the inventory when production stops.

So, in the teletypewriter field, we have talked about three main equipments—the KW-26 for high-speed point-to-point communications at generally high echelons; the KW-37 for Broadcast; and the KW-7 for multi-holder tactical operations. There are a number of other equipments used for special applications like multi-channel communications where you may need to secure up to 48 channels simultaneously; but for securing teletypewriter traffic and nothing else, these are currently the big three.

They represent significant advances in need, size, reliability, and flexibility. I failed to mention that the KW-7 will very nearly fit in a standard safe drawer.



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SIXTH LECTURE:

Multi-Purpose Equipment

Each of the equipments that I have mentioned to you was designed to take a particular kind of traffic: literal traffic—the letters of the alphabet in the case of the “KL” machines: teletypewriter traffic in the case of the “KW” machines. But as early as World War II, cryptographers and communicators were looking for ways to accommodate a variety of inputs in the same machine—they wanted, for example, a machine which would produce its cipher text in the form of five-letter groups to facilitate transmission where Morse code had to be used, and to have that same machine produce its cipher text in teletypewriter format for use where teletypewriter circuits were available. A little later, as we shall see, they wanted and got equipments containing other options like teletypewriter, and facsimile, and voice encryption all in the same package.

The Signal Corps made the first effort during WW II. It was called the SIGNIN, and was quite a monster. They tried to solve a multitude of problems in one swell flop including the age-old physical security problem we have had with crypto-equipment. They built it in its own special safe and wound up with an equipment about four feet across and weighing Lord knows how much in its solid steel olive drab package. They built their own teletypewriter keyboard instead of hooking into a standard commercial model as had been done previously and since. It would operate either on-or-off-line. The machine used rotors, a whole slew of them and, in the teletypewriter mode combined plain text and key in a novel way, all five intelligence bauds of the teletypewriter character being mixed simultaneously with 5 elements of key provided by the machine. This feature caused a brief resurgence of interest in the old monster during the early fifties, once again because of that ubiquitous problem, compromising emanations.

WW II ended before this machine had been perfected for very long, and it never got very heavy use. But the idea for doing a multiplicity of things in one machine was there. The KL-7 and KL-47 systems were coming along, and the utility of having a literal machine able to accept messages for encryption or decryption in teletypewriter punched tape form, and to produce its cipher text in this same form instead of printed on gummed tape had been recognized. Rather than building such features into the machines themselves, which would burden most of the users who had no access to teletypewriter circuits with needless added bulk and cost, a few circuits were built in to permit ancillary teletypewriter equipment to do the work when needed and available. They were called “HL” equipment—the H in the first position stands for ancillary; and L still stands for literal: so an “HL” equipment is one that aids or facilitates but does not actually perform a literal encryption process.

But we had to wait until the mid-50's for the next real multi-purpose equipment to come along. It was designed to meet Navy requirements for the processing of facsimile information or teletypewriter information. It was called the AFSAX-500—the “X” stands for facsimile or “fax” for short: AFSA stands for the Armed Forces Security Agency, which is what NSA was called until late 1953—the change was more than in name only, by the way: our responsibilities became national in scope instead of being limited to the armed forces. Thus, it was that juncture that Departments and Agencies like the Department of State and CIA came under our jurisdiction in cryptographic matters. Anyhow, the AFSAX-500 reflected our growing disillusionment with rotor techniques where high speed processes were needed. In order to encrypt facsimile information at any reasonable speed, it first has to be converted to digital form and then processed at bit rates of anywhere from 1800 bits to 2500 bits per second. Can you imagine rotors going at that speed? Neither could we nor the Navy who really designed the AFSAX-500 under the tutelage of a very famous Navy Captain named Safford. Capt. Safford had played a large part in the invention and development of most of the WW II rotor systems. What was built amounted to an electronic analog of a rotor system—it used up three bays of equipment (a bay is about the size of most of the 4-drawer safes around here.) Since the equipment had to produce lots of key for use in the facsimile mode, there was key to burn for teletype-

writer operations where the speed of the equipment remained limited by the electromechanical properties or the associated TTY equipment—(Truly fast page printing, you realize, had to wait for computers, so that not too much of their valuable time would be lost waiting for some printer to bang out its voluminous rapid-fire products.) Because this extra key was available for TTY use, the machine was built to encrypt about 5 channels of teletypewriter information simultaneously. Then, when no pictures were being sent over the facsimile channel, the communicators could unload their teletypewriter traffic backlog.

Well, the AFSAX-500 worked all right, but not very many of them were ever built: we suspect it was partly because it was *horribly* expensive although the Navy never would say just how much it cost: but there was another reason as well—that is that facsimile requirements have a habit of withering away about the time you have an equipment to serve them. This has been true over the years, and a whole class of systems with "X" in their short titles never repaid the investment that went into their development—which means, hardly anybody bought them or used them.

I want to make just two more points about the AFSAX-500; one is that it continued in use for more than 10 years, but so far as we can tell, it was used nearly exclusively for multi-channel teletypewriter encryption, not for facsimile which had been its real purpose. The other is, that yet another way for keying the equipment—for setting it up—was devised. I have described equipment which is set up from a printed key list that tells you how to put rotors together, arrange, and align them: I have mentioned key cards that use holes and no holes to establish settings in electronic equipment: and I spoke of a plugboard—which is a kind of wiring matrix—that is now being used with the KW-7. The designers of the AFSAX-500 were faced with the problem of setting up a very large number of variables each day—they could have used a very large bank of switches that could be flipped one way or another in accordance with a printed key list. This had been done with the earliest U.S. ciphony equipment—the SIGSALLY—that we'll be talking about in due course. Instead, they chose to use a long segment of one-time tape which was fed into the machine during the setup process and which established the starting configurations for its electronic "rotors". We've toyed with that idea again from time to time but, in most cases better ways have been found. Only one other system used tape segments for its setup. So now we have four different ways to set up our daily variables, and we have barely left the teletypewriter field. It suggests that this business of how to get the variables set up swiftly and accurately constitutes an inherent problem in our business, and this is so. In other courses, you will hear of still different ways being explored.

The next multi-purpose crypto-equipment I want to describe is called the TSEC/KO-6. Strangely enough, in the TSEC nomenclature scheme, that "O" meant "Multi-purpose"; but although a number of subsequent equipments with multiple capabilities were built, the KO-6 is the only one that got assigned an "O". This is because a more generic designator, "G", for *key generator* was decided on, and that's what we used thereafter whether the equipment had a multiple use or not.

But the KO-6 was invented before the TSEC nomenclature took effect, and used to be called the AFSAY-806. That "Y" stood for "ciphony" or voice encryption, and that was the primary thing the KO-6 was for. But it could also encrypt either facsimile or—like the AFSAX-500—a number of teletypewriter channels simultaneously. The designers were again faced with the problem of producing a lot of key very rapidly, but were still tied to electromechanical techniques for doing it. What they settled on had at its heart something called a geared timing mechanism (GTM) which would spin six rotor-like notched disks very rapidly and used photo-electric cells to read various notches as they went whipping by. The resultant data, in the form of 1's and 0's again (really light or no light) was combined into a random key stream, and added to digitalized plain text in the usual old binary way. This was a pretty complicated and precision-built device. We put at least one major electronics firm out of business trying to build it for us; but it worked. The last ones were deep-sixed in the latter part of 1966.

A problem looms: how do you put voice into digital form? Let me back-track a little. You have seen that we have means for producing key in binary form in a variety of ways and that, if your plain language is digital, the business of encipherment and decipherment through binary addition

and re-addition is fairly straight forward. But if we don't digitalize speech, how else might we encrypt it? The only alternative means that has gotten much play is to transpose it in various ways—record it and send it out backwards; split it up into little pieces, smaller than syllables, transpose the pieces according to some key, and reconstitute it at the receiving end; or, pull out the various frequencies of the speech and transpose these for transmission. Almost all the commercially available "speech privacy" devices use some such technique as this. But you'll recall that I told you that transposition systems are fraught with security weaknesses; and it has continued to prove true whether you are using a pencil and squared paper or very sophisticated electronics, there's just too much underlying intelligence showing through. But from time to time we try again to do something besides digitalization because it turns out that there would be very important advantages if we could: we could eliminate a battery of expensive and elaborate equipment that we now need to use just to convert the speech to digital form before we begin to encrypt it; and we could cheaply provide ciphony on *narrow-band* communications channels like HF radio and the ordinary telephone. This is now extremely difficult to do because, if you are to describe speech accurately with a series of 1's and 0's, it takes a huge number of these digits for each syllable: this in turn demands a large portion of the radio frequency spectrum, a *broad-band* signal, for transmission. The fewer digits you use to describe speech, the less spectrum you use, and the farther you can transmit it but the less intelligible the speech becomes when you reconvert to a form suitable for the human ear.

At any rate, for security reasons, we had to settle on speech digitalization as part and parcel of any ciphony system. We have three basic ways in which we now do this—vocoding (short for voice coding) which uses relatively few digits to describe speech and is hard to understand unless the vocoder is large and expensive and even then it may leave something to be desired; delta modulation, which uses many digits, gives excellent speech quality, but needs a broad band radio path or special wire-lines like coaxial cables for transmission; and pulse code modulation, which produces similarly high voice quality and has similar transmission constraints.

Since the MC's (Military Characteristics) of the KO-6 called for long-haul (HF) capability, the first of these techniques—vocoding—had to be used. Only 3,200 bits per second to describe the speech—with key stream generated at a comparable rate—were used in contrast to a contemporary system for wide-band (microwave) transmission where the bit rate was on the order of 320,000 bits per second (AFSAY-816).

Because the speech quality was so poor—you could not recognize voices—and because the system was inconvenient to use (push-to-talk procedures and very slow and deliberate speaking; and the need to walk down to or near the cryptocenter to get access to the system) the machine turned out to be less than a roaring success and over the years we were unable to document very heavy usage of it by anybody for voice communications. There did not seem to be much call for facsimile encryption, as I have mentioned, and just before the last KO-6's were retired in 1966, they were used exclusively to encrypt multi-channel teletypewriter traffic.

We're going to come back to the whole subject of speech encryption devices and trace their evolution in some detail. But before we get to that subject, there is one more family of multi-purpose equipments I want to talk about. These are the KG-3/KG-13 series of equipments.

Until around 1960, as I have indicated, each new crypto-equipment was tied to rather specific communications means, and was built to be compatible with input devices like teletypewriters or facsimile equipment with very specific characteristics. Even those multi-purpose devices we have described could work only at a few specific speeds; the KO-6 would work only with the specific vocoder we built to go with it and not with any other speech digitalizer. This specificity of purpose caused the equipments to be inflexible and tended to make them obsolete relatively quickly as new communications techniques and input devices became available. So we did a philosophical about face with the KG-3. We said, why not build a pure and simple key generator divorced from any specific input device or digitalizer: simply an equipment which will put out good random digital key with a large variety of speeds, and a mixing or binary addition component that will accept the encipher and digital signal delivered to it? If somebody wanted to encrypt teletypewriter traffic, or facsimile, or data, or voice, he would provide the equipment that would deliver that information in

binary digital form to the key generator and it would do the rest. And so the KG-3 was born—a straightforward key generator with a randomizer, a power supply, and timing circuits to permit speeds varying from 1 to 100,000 bits per second, and that's about all. And this idea worked fairly well. We had gotten ourselves out of the communications business into which we had become increasingly involved, and back to pure cryptography where we thought we belonged. But there were some difficulties. Because the KG-3 was a single key generator, it could only process traffic in one direction at a time; this meant that to accommodate the full-duplex operations that almost everybody needed, two complete equipments had to be set up at each end of each circuit, and this was a waste. There was no reason why a send and receive key generator could not share the same power supply, thus eliminating one of them, and the same timing circuits, and you really did not need a randomizer in the receiving equipment at all because all the receiving equipment needs to do is to accept the random indicators generated at the distant station; the *send* equipment does the randomizing.

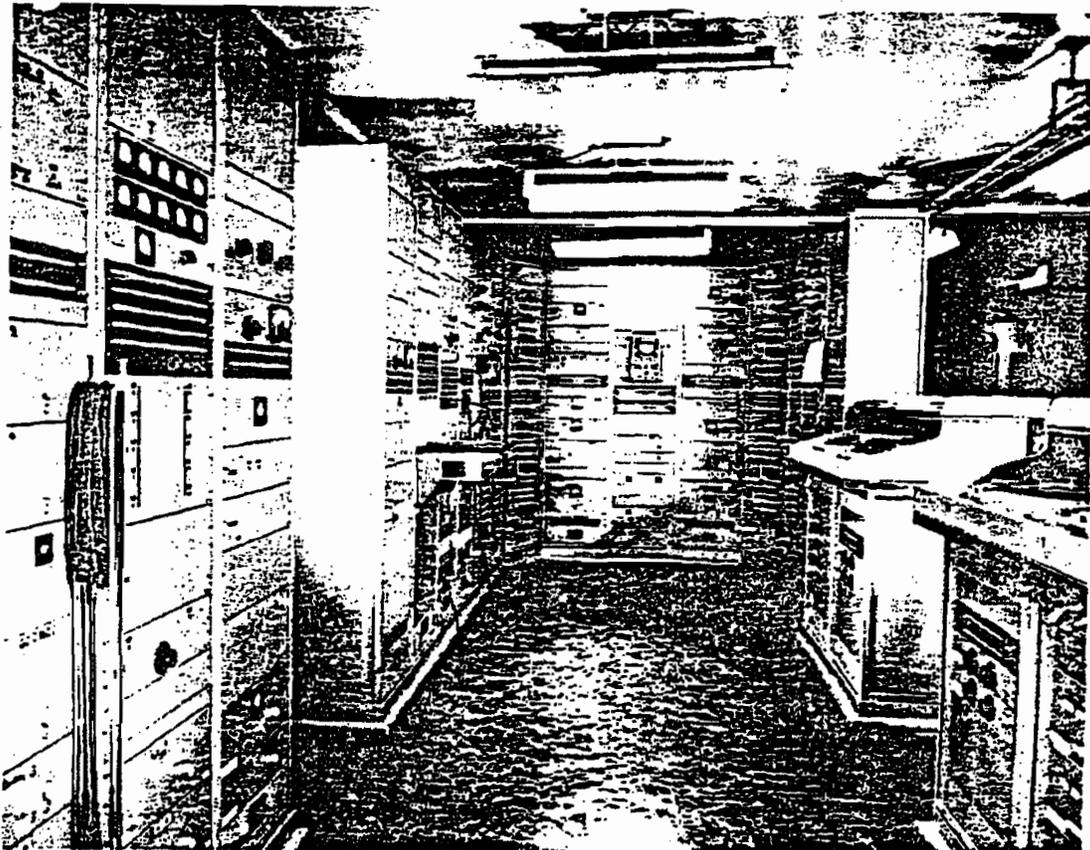
So, the KG-13 was built: it amounts to a pair of KG-3's one used for sending and containing all of the original KG-3 features; the other for receiving and stripped of all the components and functions that the send equipment can supply.

We have now traced the checkered history of multi-purpose equipment and have seen that it took from 1944 or so until 1960 to come up with one that did not really have a single primary purpose in mind with other capabilities included as side benefits. The SIGNIN was primarily for teletype-writer traffic; the AFSAX-500 was for facsimile; and the KO-6 was for voice. The KG-3/13 was for *anything* digital with speeds up to 100 KHz.

SEVENTH LECTURE: Ciphony Equipment and Other Specialized Systems

Ciphony Equipment.—You have already had a preview of some of the problems of voice encryption in the discussion of the KO-6. Since by far the greatest weakness in U.S. COMSEC today stems from the fact that almost all of our voice communications are sent in the clear, the business of finding economical secure ways to secure voice transmissions remains a burning issue and is consuming a good part of our current COMSEC R&D effort.

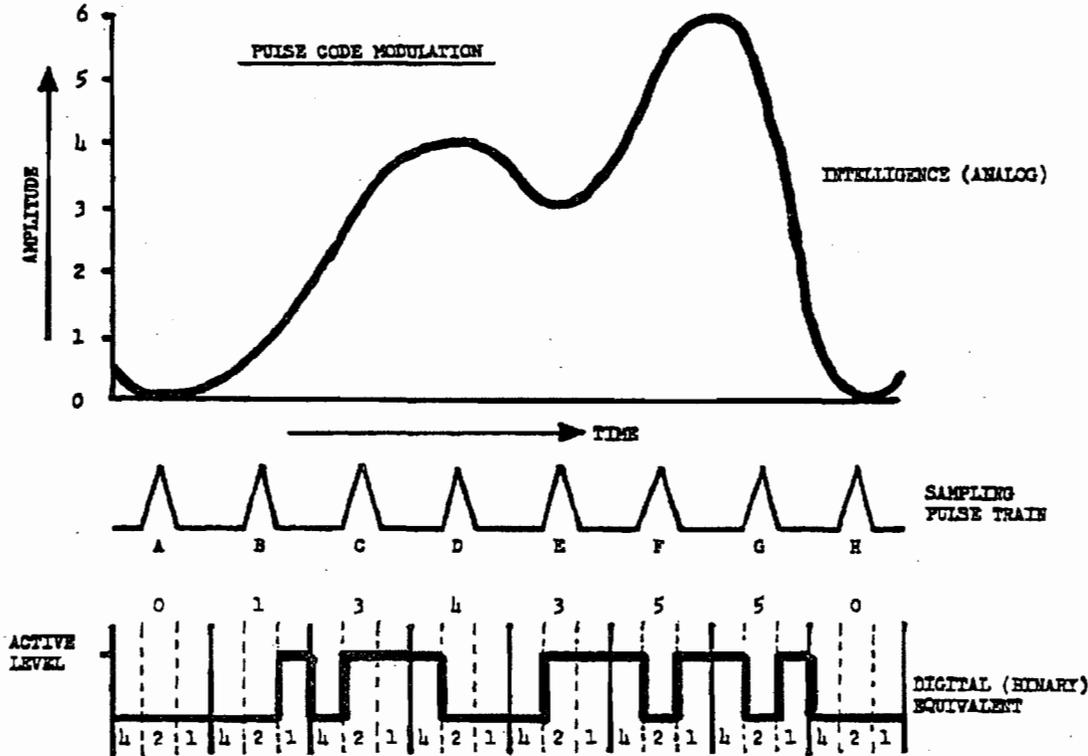
We have to go back to World War II for a look at our first voice encryption equipment:



This looks like a whole communications center or laboratory or something; but it's all one cipher machine. It was called SIGSALLY. If you counted the air-conditioners that had to go with it, it weighed something like 55 tons. It was used over the transatlantic cable for communication between Washington and London. It used vacuum tubes by the thousands, and had a primitive vocoder. It was hardly the answer to the dream of universal ciphony, and was dismantled soon after the war ended.

The next ciphony system to come along was called the AFSAY-816. It was designed to operate over microwave links—actually, just one link—between the Naval Security Station and Arlington Hall. Since there was plenty of bandwidth to play with (50 KHz), there were no constraints on the number of digits that could be used to convert speech into digital form. The technique used was

called Pulse Code Modulation (PCM): conceptually, it involves sampling the amplitude (size) of an intelligence signal, such as one's voice, at fixed intervals of time determined by a high frequency pulse train, then transmitting the values thus obtained in some sort of binary or baudot code. The following illustration portrays these relationships:



The AFSAY-816 used a primitive vacuum tube key generator with bank after bank of shift registers . . . and, for the first time, we were able to put out more key than we could use. So we used it to provide for encryption of several channels of speech simultaneously. Speech quality was good, reliability was spotty, and security, especially in its last years was marginal since it was in about that time frame that we began to be able to postulate practical high-speed computer techniques as a cryptanalytical tool. We hastened to replace the equipment with one called the KY-11. The KY-11 was the first relatively modern key generator of the breed I described in the KW-26. Instead of using the Fibonacci principle, however, it used something called "cipher text autokey" or "CTAK" for short. I'll tell you something more of the uses to which this principle can be put later.

At any rate, we lived on borrowed time with the AFSAY-816 and on the hope that, because its transmitted signal was fast, complex, and directional, hostile interception and recording would be impracticable.

Don't think for a minute that the same rationale isn't used today for unsecured circuits that happen to use sophisticated transmission techniques. A favorite ploy of the manufacturers of forward tropospheric and ionospheric scatter transmission systems, for example, is to advertise them as inherently secure because of their directivity and because they are beamed over the horizon and theoretically bounce down in only one place. However, because of atmospheric anomalies; it is impossible to predict with certainty what the state of the ionosphere will be at any particular moment. It is because of these anomalies that the reflection of the transmitted signal from the ionosphere is subject to considerable variation and, consequently, subject to interception at an

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unintended location. As a matter of fact, there was a "permanently" anomalous situation over parts of Southeast Asia that caused VHF communications to double their expected range.

The general attitude of this Agency is that no deliberate transmission is free from the possibility of hostile interception. The thought is that there is really a contradiction in terms of the notion of an uninterceptible transmission: for, if there were such, the *intended* recipient, your own distant receiver, could not pick it up.

Despite all of this, it is clear that some transmissions are considerably more difficult and costly to intercept than others and some of them carrying information of low intelligence value may not be worth that cost to the potential hostile interceptor. These factors have a lot to do with the *priorities* we establish for providing cryptosystems to various kinds of communications entities.

But, in the case of voice, which is our subject, it has not been any rationale of non-interceptibility which has slowed us down, it is the set of terrifically difficult technical barriers in the way of getting such equipment in light, cheap, efficient, secure form, either for strategic high-level links, as in the case of all the ciphony equipments I've mentioned so far, or for tactical circuits that we will, in due course, cover.

Still, with the advent of the KY-11, it appeared that we had at least one part of the ciphony problem relatively well in hand: that was for fixed-plant, short-range operations where plenty of bandwidth was available for transmission. These fixed-plant, wide-band equipments—all of them—not only could provide secure good quality voice, but had enough room to permit the encryption of several channels of voice with the same key generator. But just as in the case of teletypewriter security devices, there was a need to move ciphony equipment out of the cryptocenter and nearer to the environment where the actual user could have more ready access. In the case of the teletypewriter encryption systems, you will recall, the move was into the communications center where all the ancillary devices and communications terminal equipment and punched message tapes and message forms were readily available. In the case of ciphony, the real user was the individual who picks up the handset and talks—not some professional cryptographer or communicator—but people like you and me and generals and admirals and presidents. So the next need we faced was to provide an equipment which could be remote from both cryptocenter and communications center, and used right in the offices where the actual business of government and strategic military affairs is conducted. This called for machinery that was smaller and packaged differently than any of the ciphony equipment we have talked about thus far. SIGSALLY you remember, weighed 55 tons; the next system weighed a lot less but still needed 6 bays of equipment. The KY-11 was smaller still, amounting to a couple of racks of equipment configured for communications center use. None of them were at all suitable for installation in somebody's office.

The resultant product was called the TSEC/KY-1. The most striking feature it had, in contrast to its predecessor ciphony devices, was that it was neatly packaged in a single cabinet about two-thirds as tall and somewhat fatter than an ordinary safe. Because it was built not to be in a cryptocenter or a classified communications center where there are guards and controls on access to prevent theft of equipment and their supporting materials, this KY-1 cabinet was in fact a three-combination safe that contained the whole key generator, the power supply, the digitalizing voice preparation components—everything except the handset which sits on top.

So, for the first time since World War II with the SIGNIN, we found ourselves building physical protective measures into the equipment itself. The safe is not a particularly good one—hardly any are—but it is adequate to prevent really easy access to the classified components and keying data contained inside. Microwave links or special wire lines were used to transmit its 50 KHz cipher text. The principle was CTAK again: and it had the capacity to link up to 50 holders through some kind of switchboard in a common key. The first network was used here in Washington and served key officials of government—the President, the Secretary of Defense, the Secretary of State, the Director, Central Intelligence Agency, and some others. We soon found that the equipment needed to be installed not only in key government offices, but in the private residences of key officials as well, so that they could consult securely in times of crisis night or day. I think the first such residence was

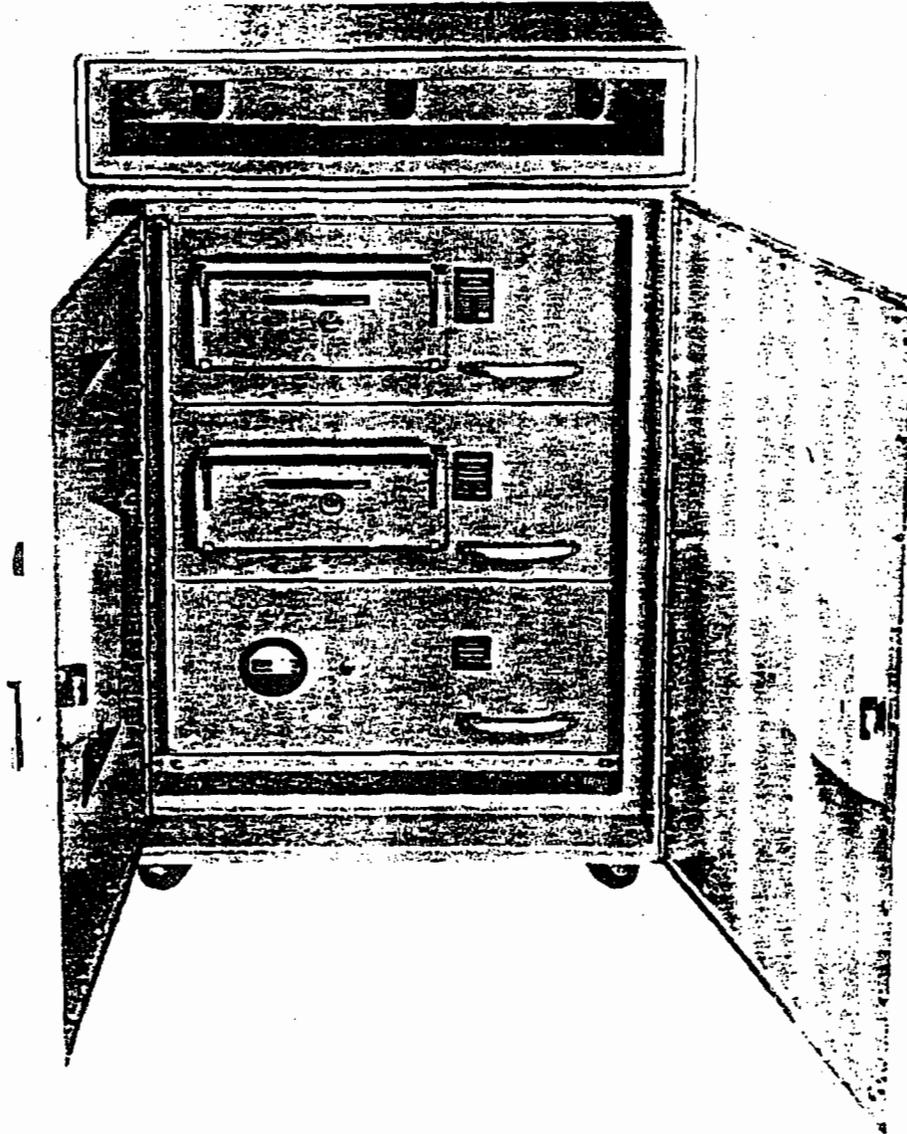
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President Eisenhower's Gettysburg address: later such equipments were used in the homes of a number of other officials.

The KY-1 had some limitations, as almost all first tries at a new requirement seem to: it was essentially a push-to-talk system which annoys most users and makes it impossible to interrupt conversations. Eventually, the cryptanalysts discovered some new possible attacks that lowered our confidence in its security and so the KY-1 was retired in early 1967. This KY-3 is the follow-on equipment to the KY-1. It provides a duplex (no push-to-talk) capability and some security and operational refinements.



This is perhaps as good as a place as any to go off on another of the tangents that seem to characterize these lectures. As we have been following the evolution of U.S. cryptography, I have talked

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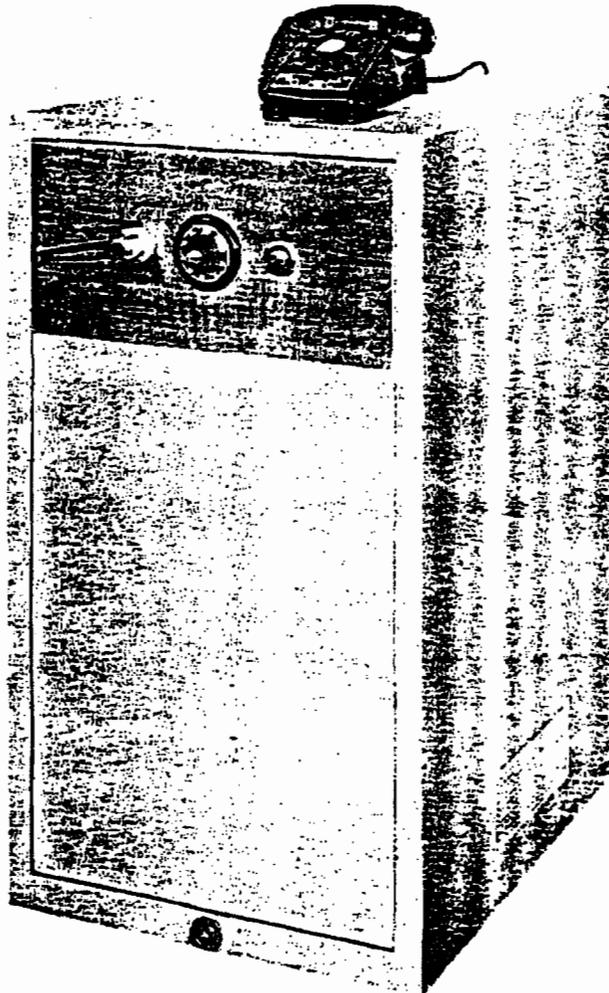
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quite casually of new equipments coming into our inventory and old ones fading away. In retrospect, the demise of the obsolescent, inefficient, and insecure systems seems natural, easy, inevitable, and relatively painless. But the fact of the matter is that it is usually quite difficult to get the users to relinquish any equipment once it is solidly entrenched in their inventories—especially if it works well, as in the case of the KY-1; but even if it doesn't, as in the case of the KW-9. The reluctance to junk old systems stems from a number of causes, I think. First of all, they represent a large investment; secondly, the users have developed a supporting logistic base for the systems, have trained personnel to operate and maintain it—they've *used* it. Finally, the introduction of a new system is a slow and difficult business requiring new budgetary and procurement action, new training, the establishment of a new logistics base, and—increasingly these days—a costly installation job to match the new system to the facility and communications system in which it is to be used. Because of these problems, our "equipment retirement program" is a halting one, and only when there are very grave *security* shortcomings can we actually *demand* that a system be retired on some specific date. Well, back to ciphony systems.

With all these developments, we are still talking about equipment that weighs several hundred pounds, is quite expensive, and which is limited to specialized and costly communications links. Except in the case of the KO-6, these links are relatively short range.

So, at the same time these wide-band fixed-plant equipments are being developed, we were working on something better than the KO-6 to satisfy long-range, narrow-band communications requirements, something that could, hopefully, be used on ordinary telephone lines or on HF radio circuits overseas. (Ma Bell's telephone system, you understand, has a bandwidth of only 3 KHz—and still has a few quick and dirty WW II links in the mid-west with only a 1500 hertz bandwidth. This situation, as I have said, sharply limits the number of digits we can use to describe speech to be encrypted on such circuits with a consequent loss of quality of intelligibility.)

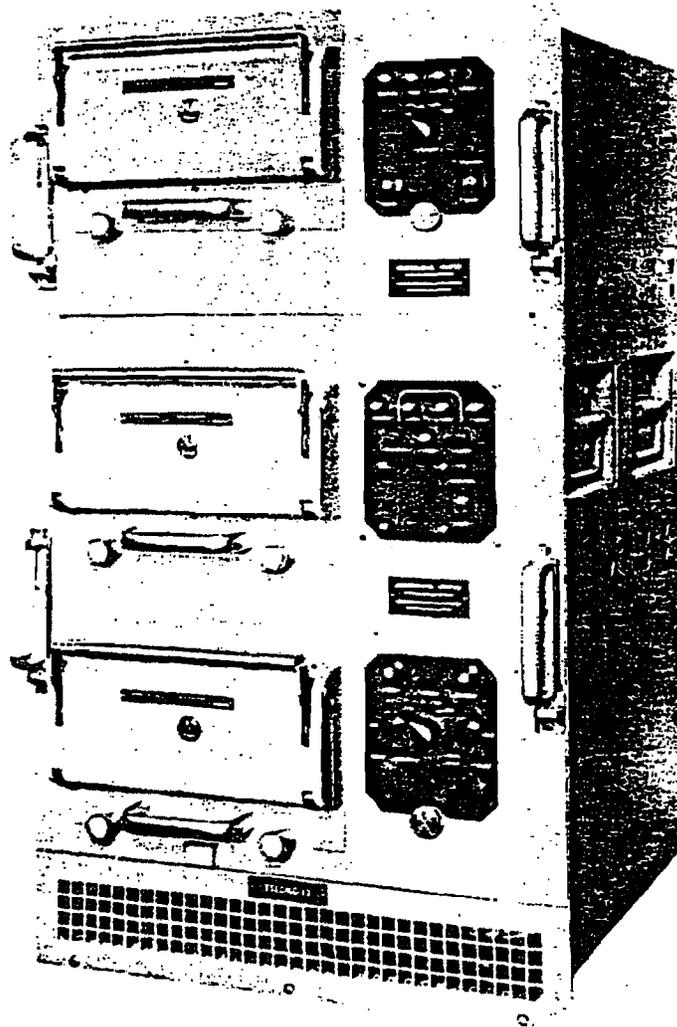
The equipment which evolved is called the KY-9.



The KY-9 used a vocoder as did its narrow-band predecessors, but a more sophisticated one than had been developed thus far. It was the first of the vocoders to use transistors instead of vacuum tubes, so that the equipment could be reduced to a single cabinet. But transistors were in their infancy; and the ones that went into the KY-9 were hand-made and expensive. Again the equipment was packaged into a safe so that it could be located in an office-type environment. Well, we were getting there: we could use an ordinary telephone line with the KY-9, but the speech still sounds artificial and strained because of that vocoder, and . . . you . . . must . . . speak . . . very . . . slowly . . . and . . . distinctly and you must still push to talk. And besides all that, this bear initially cost on the order of \$40,000 per terminal which put it strictly in the luxury category. About 260 KY-9's are in use for high-level, long-haul voice security communications. The majority of the KY-9 subscribers are now being provided this secure capability through use of the Automatic Secure Voice Communications (AUTOSEVOCOM) system; however, it is anticipated that the equipment will remain in use at least through FY-74. Beyond FY-74, the equipment may be declared excess and stored for contingency purposes.

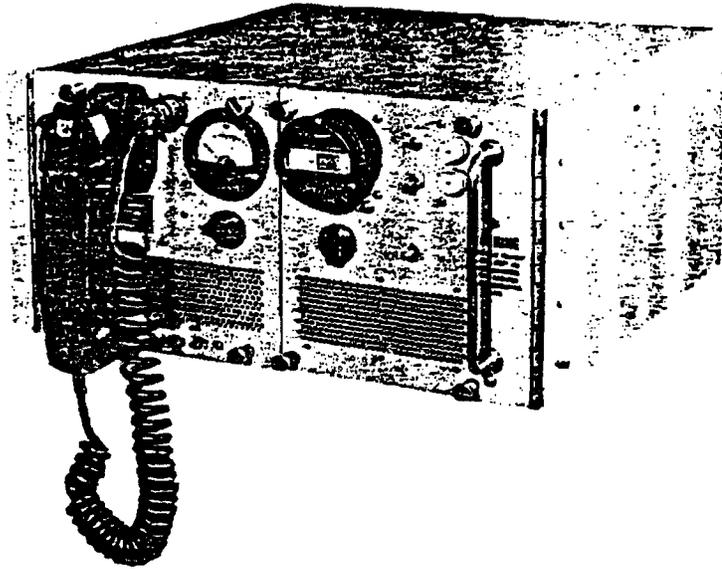
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The best and newest long-haul voice equipment uses none other than our multi-purpose friend, the KG-13. Nobody came along with a nice vocoding speech digitalizer to hook into this key generator, and there's really not much call to process speech this way unless you're going to encrypt it, so we wound up—again—having to build some of the ancillary equipment ourselves. This equipment is called the HY-2—remember, the H stands for *ancillary*, the Y for *speech encryption*. So the combination referred to as the KG-13/HY-2 is the system we are now counting on to serve the long-haul voice requirement.



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Again, a vocoder was used, and this sounds the best yet, although it still can't match the voice quality that wide-band systems have. This package is not in a safe, and is not suitable for office installation, but it seems to satisfy most of the other long-haul requirements well and does so fairly heply for the first time.

Before we talk about tactical voice security equipment, there is a subject related to the big fixed-voice equipments we ought to talk about. That's the subject of "approved" circuits. Way back with the KO-6, we were having difficulty getting officials to leave their offices and walk to a cryptocenter to use a secure phone. The solution lay in carrying the system or at least the telephone handset (which is all he really needs or cares about) to him. This involved running a wire line from an office to the cryptocenter or secure communications center. The difficulty with this solution is twofold: in the first place there was and is a long-standing Executive Order of the President governing the way classified information may be handled, transmitted, and stored: and in the case of TOP SECRET information, this order forbids electrical transmission *except in encrypted form*. Of course, the information is in the clear, not encrypted, until it reaches the cryptomachine, and this meant that any time one placed that handset remote from the machine, the user, by "law" had to be restricted to conversations no higher than SECRET. This is difficult to legislate and control, and reduces the usefulness of the whole system. The second difficulty in this situation stems from the security reasoning lying behind that Executive Order. The reasoning was, and is, that it is extremely difficult to assure that no one will tap any subscriber line such as this, if it is not confined to a very carefully controlled area like a cryptocenter or classified communications center. It means that if you are to use these subscriber lines in some government installation, the whole building or complex of buildings must be extremely well guarded, access carefully controlled, or personnel cleared or escorted all the time. Controls such as we have here are simply not feasible in a facility such as the Pentagon or on a typical military post: yet it is in just such environments that these protected wire-lines may be needed.

Some special rules govern communications used to support SIGINT operations, and these rules have been interpreted to permit TOP SECRET traffic such as we use on the grey phone system here—provided certain physical and electronic safeguards are enforced. The JCS applied the same sort of criteria in staffing an action which permitted TOP SECRET information to be passed in the clear over wire lines when certain rigid criteria are met. Until this action went through, we were unable to make full use of the ciphony capability we now have in systems such as the KG-13/HY-2.

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and subscribers were held to SECRET unless they were essentially co-located with the crypto-equipment itself.

Tactical Ciphony.—MC's for tactical ciphony equipment—be they broad-band, narrow-band, or somewhere in between—have existed since before this Agency was created. But the difficulties were terrific. To have tactical usage on field telephones and radio telephones and military vehicles and, especially, in aircraft, the equipment had to be truly light, small, and rugged; and had to be compatible with a large variety of tactical communications systems most of which are not compatible among themselves. In the case of aircraft requirements, there's an old saying that the Air Force will reject any system unless it has no weight, occupies no space, is free, and adds lift to aircraft. We were about ready to believe this in the late fifties when we had gotten a tactical ciphony device, the KY-8, down to about 2/3 of a cubic foot, and it was still not accepted, mainly because it took up too much room. The ironic part of this sad story is that the cryptologic portion of the hardware uses only a modest amount of space: its power supplies and the digitalizers for speech that use up the room. The Air Force did give that small equipment, the KY-8, a good try in high performance aircraft like F-100's: it worked fairly well, but sometimes reduced the effective range of their radios about 5%, a degradation of their basic communications capability they simply could not afford. Besides, the problem of lack of space proved very real and they had to rip out one of their fire-control radars to make room for the test equipment.

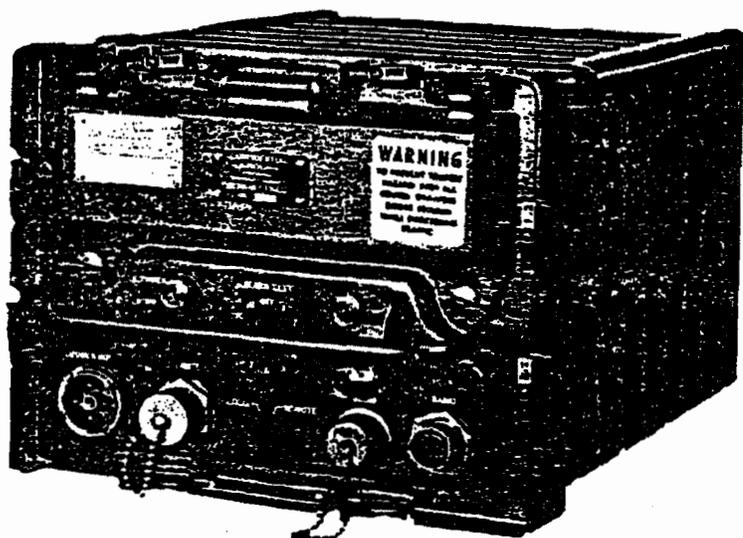
Then the Army decided it could use the KY-8, mounting it in jeeps and other wheeled vehicles where space was not so critical as in aircraft. We had attempted to make a ground tactical ciphony equipment for Army, called the KY-4, but it didn't pan out; and the Army had independently tried to develop a tactical voice device that was equally unsuccessful. So Army bought a batch of KY-8's and they and the Marines became the principal users, even though it was really originally designed for aircraft.

There's another point about the KY-8. I've made it sound as if over-choosy users have been the only cause for its slowness in coming and limited use. That's not quite the case. There were some security problems—the compromising emanation business again—that slowed down our production for some time: we finally got going full blast on this equipment by cancelling out most of the delaying features in the contract associated with the radiation problem, accepting this possible security weakness as a calculated risk, and placing some restrictions on where the equipment could be used to minimize that risk.

Today we have a family of compatible, tactical, speech security equipments known as NESTOR—the KY-8/28/38. The KY-8 is used in vehicular and afloat applications; the KY-28 is the airborne version; and the KY-38 is the portable or man-pack model. There are currently about 27,000 NESTOR equipments in the U.S. inventory. No further procurement of NESTOR equipments is planned because the VINSON equipment is intended to satisfy future requirements for wide-band tactical voice security.

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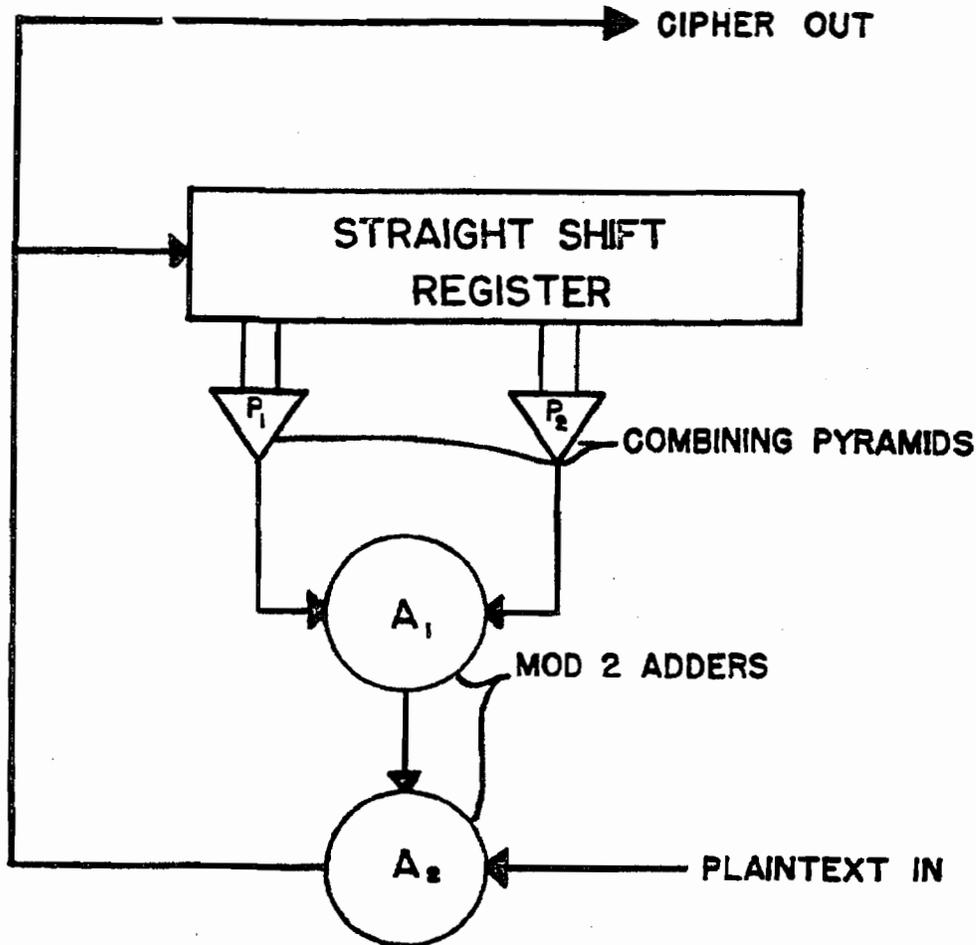
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Cipher Text Auto-Key.—We have seen that, in seeking means to produce one or many streams random key to combine with digitalized plaintext information, we have settled on several mathematical principles such as Koken, Fibonacci and CTAK and that one of the technical problems associated with these techniques is the matter of keeping the local and remote key generators in step. I have said that another problem is the supply, with each new message, of some random information to the distant station, in the form of an indicator, to provide unique settings within the day's key for each new transmission. A principal means for doing this with the electronic systems has been the use of a "randomizer" that sends out a burst of random and unpredictable digits at the start of each message. This presents two difficulties: the first is that the loss or garbling of any one of these digits in transmission—and the stream may be up to 260 bits long—will cause the distant machine to be set up incorrectly, and decipherment will not be possible. In some systems, this difficulty is partially overcome by repeating each digit a number of times—the indicators are redundant and the receiver can select the correct digit by using that majority vote technique we discussed with the KW-37 broadcast system. But this method is not altogether satisfactory—it complicates the hardware for one thing. Another difficulty, with or without the use of a randomizer to effect initial message setups, is this business of keeping the machines synchronized after actual encryption is in process. In the case of equipments like the KW-26 and the KW-37, this is done by clock systems that send out periodic timing pulses—but again, the hardware involved may be rather elaborate. In any multiple holder system that does not have "catch-up" features in the receivers, i.e., with *anything* but a KW-37, the difficulty of getting everybody started at once is serious.

If the designers could find a way to use the cipher text itself instead of a randomizer as the source of new random information with each transmission, and could also use that cipher text as a basis for timing, the equipment would be simplified. The result was the development of *cipher-text auto key* systems. The cipher text was delivered to the binary address of the receiving equipment, there recombined with key to effect decipherment in the usual way, but at the same time, it was fed into a set of shift registers which formed part of the key generator itself and was used there to form the key to be used in deciphering subsequent incoming cipher information.

CIPHER TEXT AUTO KEY



At the same time, this solved the problem of synchrony because, provided that the proper cipher text was received, the receiving equipment could derive proper key, with the correct timing, from that cipher text itself. There remained one major problem. We have said that in an ordinary key generator, the garble of a character in transmission will cause only one (actually two) characters to garble in the deciphered plain text. But as you'll note in the diagram we have had to fill a shift register with cipher text in the auto-key system; a single garble in this case spoils the key until the garble has shifted its way through the whole register—typically about 15 to 37 characters. This means that a single garble in transmission will cause up to 38 digits to be garbled in the deciphered text. This means that if this technique is used with something like teletypewriter traffic, the transmission path must be very reliable; otherwise there will be too many long stretches of gibberish in the received messages which the communicators can't tolerate—in fact, one such teletypewriter encryption equipment failed its user tests exclusively for this reason. But if the underlying plain text is something like digitalized speech, where thousands or 10's of thousands of digits go into each

syllable, the loss of this handful of digits is trivial: the effect is so brief a slur in the deciphered speech as to be inaudible. The first system using the auto-key technique was the KY-11 as I mentioned earlier. A half-dozen other machines, mostly ciphony equipments also use this principle.

From the operational point of view, the effect of a system such as this is that any receiver can pick up a transmission in mid-stream just as KW-37 receivers can, but without the elaborate clocks and high-speed catch-up mechanisms. With auto-key, the receiver merely waits until it has received enough cipher characters to fill its shift register, and then begins decipherment.

We have now covered the major equipments and principles in use today. The big systems are:

- For Literal Traffic: The KL-7/47
- For Teletypewriter Traffic: The KW-26, KW-37, KW-7
- For Ciphony: The KY-3, KY-8, KY-9 (KG-13/HY-2)
- For Multi-purpose: The KG-3/KG-13

All the principles in the current major electronic key generators involve binary addition of random key streams to digitalized plain language. The big-name principles again are *Fibonacci*, *Koken* (There is also something called *Kokenacci*, combining the features of both) and *cipher-text auto key*.

We have also talked of a number of electro-mechanical equipments that are dead or dying: one-time tape systems, and the KO-6 with its geared timing mechanism being most representative.

The variety of systems which have evolved has stemmed from needs for more efficiency, speed, security and the like: but, more fundamentally, from (1) the need to encrypt different kinds of information—literal traffic, TTY, data, facsimile, TV, and voice, (2) the need to suit encryption systems to a variety of communications means—wire lines, narrow-band and broad-band radio circuits, single-channel and multiplex communications, tactical and fixed-plant communications facilities; and (3) the need to suit these systems to a variety of physical environments.

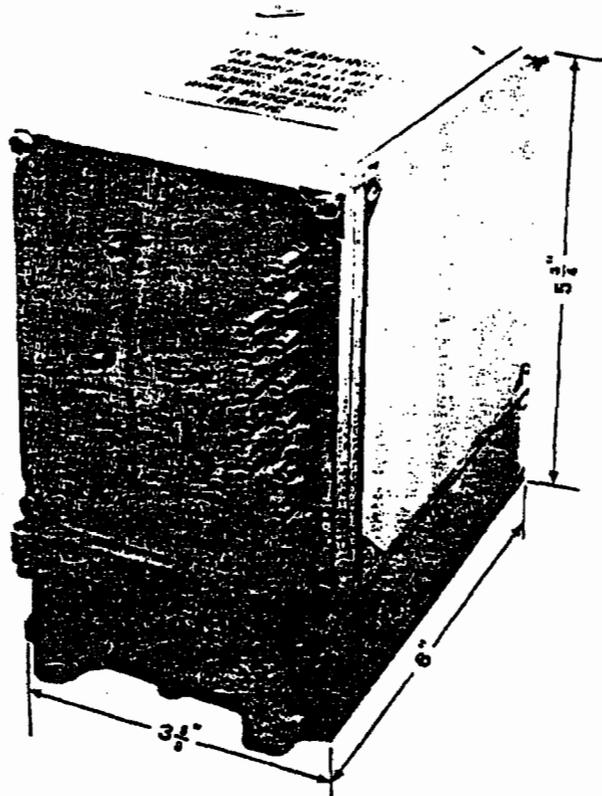
Specialized Systems.—There are two other types of systems now in the inventory beyond those I have described that I want to touch on briefly. I have left them till last because they are among the most specialized and have as yet seen relatively little use in comparison with the big systems we have talked about. The first of these is the KG-24, designed for the encryption of TV signals—division we call it. With the requirement for encrypting TV signals, we found ourselves faced with the problem of generating key at extremely high speeds, even by computer standards. So far, the fastest system I have described to you was the old AFSAY-816 with a bit-rate of 320 KHz—but this took six bays of equipment and had security, operational, and maintenance problems almost from the outset. Among the modern systems, the KG-3/13, with bit rates up to 100 kilobits was the fastest. But, as you know, with your home TV set, you tune to megahertz instead of kilohertz and it takes millions of bits each second to describe and transmit these TV signals. The KG-24 does it, and in one fairly large cabinet. During the development, radiation reared its ugly head again, and much of the cost and delay in getting this equipment could be attributed to the efforts that went into suppression of these compromising emanations. When I cover the radiation problem I'll show why there are special difficulties when very high speed signals are generated and show you the solution that was chosen in the particular case of the KG-24. The KG-24 uses the Fibonacci principle and works alright. But there are only 6 (V-1) and 7 (V-2) models in existence, and further procurement is not planned. The main thing wrong with it is simply that it costs much too much.

The second type of modern specialized system I want to talk about is the family of equipment designed specifically to go into space vehicles. There were some obvious and some not-so-obvious difficulties that had to be met in the design of these equipments. One obvious problem was to make them small enough, and this requirement gave a big push to our general work in the micro-miniaturization of hardware. The second problem was also inherent in space technology—that was the need for extreme reliability. For unmanned surveillance satellites, if the system fails, you can't call maintenance man. So we were faced with more rigid specifications and quality controls than we

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had ever seen before. The third problem has to do with the extraordinary complexity of satellite systems as a whole. We have found it next to impossible to provide decent crypto-equipment for our customers without a very full understanding of the whole communications and operations complex in which they are to operate. With our limited manpower, this has proven difficult enough to do with modern conventional communications systems and switching complexes on the ground but, for the space requirements, we had to educate our people to speak and understand the language of this new technology; and we have a little group who live and breathe this problem to the exclusion of nearly everything else.

And finally, we had to throw a lot of our basic *methodology* out the window. Every machine I have talked to you about so far, without exception, is built to have some of its variables changed at least once each day, and some of them more often. Everyone of them is classified and *accountable*: can you imagine how a crypto-custodian, charged with the specific responsibility of vouching for the whereabouts of a classified machine or classified key felt upon watching one of his precious items go rocketing off into space? Of course, we decided that we ought to "drop" accountability at the time of loss, although "lift" accountability might have been a more appropriate term. In any event, here's one of these key generators we use in space:



What we built into it was a principle that would put out a key that would not repeat itself for a very long period of time—weeks or months or years, whatever was required. Actually, with many of these new key generators, the matter of assuring a very long unrepeated sequence or, as we call it, a *long cycle*, is not so difficult. Even something as the KO-6 with its geared timing mechanism and just six metal disks would run full tilt for something like 33 years before the disks would reach

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their original alignment again, and the daily change of its key was incorporated mainly to limit the scope of any loss that might occur—that business of supersession and compartmentation again. So this little jewel is a unique one-time key generator, good for the life of its parent satellite. That random initial setup of its key generator is wired right into it at the start instead of being controlled by a key card or a set of switches. What we use is a special *plug*, manufactured right here, that sets up unique connections within the generator and establishes the basis for the generation of one long unique key. So far, these things are working well—one technical security problem has been encountered. Radiation again! I hinted in talking about the KG-24 that very high bit rates create certain radiation problems; it turns out that the location of components that process intelligence very close to *transmitting* circuitry also causes problems and, in a satellite, you simply can't get them very far apart.

We have several such systems now. We don't talk about them very much because the whole question of surveillance satellites is a very sensitive one and, of course, that's what these are used for.

Before moving on, there are a few more things you ought to know about the nomenclature system and the equipment development cycle we have touched on from time to time already. The first point is that the TSEC nomenclature we have is *not* assigned to an equipment until it has been worked on by R&D for some time and they have done feasibility studies and have, perhaps, hand-made all or portions of it to figure out the circuitry or mechanical linkages to see if the thing will work. These very early versions are called "bread-board" models, and are likely to bear little or no resemblance to the final product. R&D assigns cover names to these projects in order to identify them conveniently—the only clue to the nature of the beast involved is contained in the first letter of what ever name they assign. The letters generally correspond to the equipment-type designator in the TSEC scheme—with "W" standing for TTY, "Y" for ciphony, etc. So, in the early R&D stage, "YACKMAN" stood for a voice equipment; "WALLER" for a TTY equipment, "GATLING" for a generator, etc.

When it looks like a development is going to come to fruition, TSEC nomenclature is assigned, and *suffixes* are added to the basic designators to indicate the stage reached in each model: these can involve experimental models (designated X), development models (designated D), test models (T), pre-production models (P), and finally, with the first full scale production model, no suffix at all.

So there could have been versions of the KW-26 successively called: W-; KW-26-X; KW-26-D; KW-26-T; KW-26-P, and the first operational equipment called merely KW-26. But, in fact, when some of the early models come out well enough, some of these stages may be skipped; in fact, most of them were with the KW-26, and it has been increasingly the trend to skip as many as possible to save time and money.

But this tortuous path of nomenclating does not end, even here. *After* the equipment gets into production, more often than not, some modifications need to be made to it and, when this occurs, we need some means of differentiating them, mainly for maintenance and logistical reasons, and the suffixes A, B, C, etc., are assigned. So, in fact, we now have four operational versions of the KW-26: the KW-26-A, the KW-26-B, KW-26-C, and KW-26-D.

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The following two tables show our current system for assigning nomenclature to both COMSEC keying material and COMSEC equipment:

TABLE I
COMSEC KEYING MATERIAL

Release	Functional Relationship	Purpose	Type Aid
US — Indicates item is NOFORN	C — NUCLEAR Command & Control	A — Operational	A — Authenticator
A — Indicates item is authorized for release to specified allies	K — Cryptographic	M — Maintenance/Test	C — Code
	H — Ancillary	S — Sample	F — Cryptographic Program
	M — Manufacturing	T — Training	G — General Publication
	N — Noncryptographic	X — Exercise	I — Recognition/Identification
	S — Special purpose	B — Compatible Multiple Keying Variable	J — Indicator List
		V — Developmental	K — Key List
			L — Miscellaneous
			M — Maintenance Manual
			N — Computer Keying Material
			O — Operating Manual
			P — One-Time Pad
			R — Rotor
			S — Sealed Systems
			T — One-Time Tape
			W — Crib
			X — Fan Fold
			Y — Key Card
			Z — Permuting Plug
			B — Diagnostic Test Program
			D — Unassigned
			E — Unassigned
			H — Unassigned
			Q — Unassigned
			U — Unassigned
			V — Unassigned

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TABLE II
COMSEC EQUIPMENT

I Function	II Type	III Assemblies	IV How to Compare
C — COMSEC Equipment System	G — Key Generation	A — Advancing	1. The nomenclature designator "TSEC" followed by a slant (/) and a diagraph formed with letters selected from columns I & II indicates an equipment or equipment system i.e., TSEC/KG, TSEC/CY.
K — Cryptographic	I — Data Transmission	B — Base on Cabinet	
H — Ancillary	L — Literal Conversion	C — Combining	2. The nomenclature designator "TSEC" followed by a slant (/) and a trigraph formed with letters selected from columns I, II & III indicates a cryptographic component i.e., KGP is a power supply for a cryptographic key generator.
M — Manufacturing	N — Signal Conversion	D — Drawer, Panel	
N — Noncryptographic	O — Multi-Purpose	E — Strip, Chassis	
S — Special Purpose	P — Materials Production	F — Frame, Rack	
	S — Special Purpose	G — Key Generator	
	T — Testing, Checking	H — Key Board	
	U — Television	I — Translator, Reader	
	W — Teletypewriter	J — Speech Processing	
	X — Facsimile	K — Keying	
	Y — Speech	L — Repeater	
		M — Memory, Storage	
		O — Observation	
		P — Power Supply	
		R — Receiver	
		S — Synchronizing	
		T — Transmitter	
		U — Printer	
		V — Removable COMSEC Component	
		W — Logic Programmer Programming	
		X — Special Purpose	
		Element Designators	
		E — Plus an alphabetical trigraph	
		Sub-Assemblies	
		Z — Plus an alphabetical trigraph	

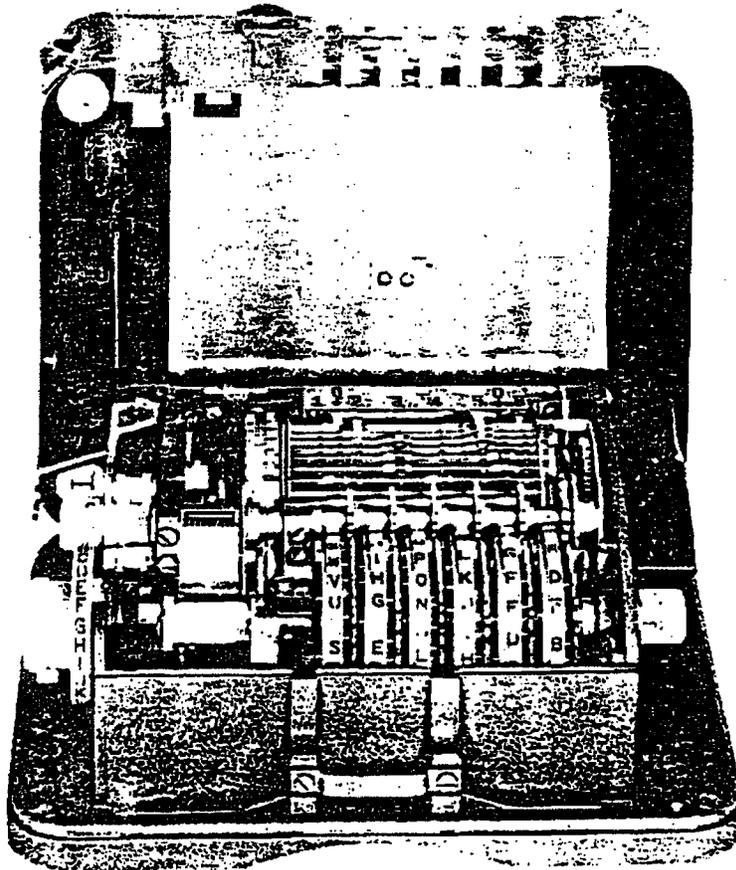
EIGHTH LECTURE:

Flops

The next topic we will cover is that of "Flops". In almost all of the basic types or categories of hardware we have talked about such as the literal equipments, TTY equipments, voice equipments, etc., we've created at least one essentially finished product that failed when it met the last hurdle before full-scale production—the Service or "user" tests. Of course, additionally we have made literally dozens of "paper and pencil" systems and simple manual encryption aids (which we call "devices" as distinguished from equipments) that flunked the course for one reason or another.

We're going to talk about some of the more representative of our failures and try to look at some of the causes of those failures with the hope that you profit from the mistakes involved and not be led down the same garden paths as you become embroiled in future developments.

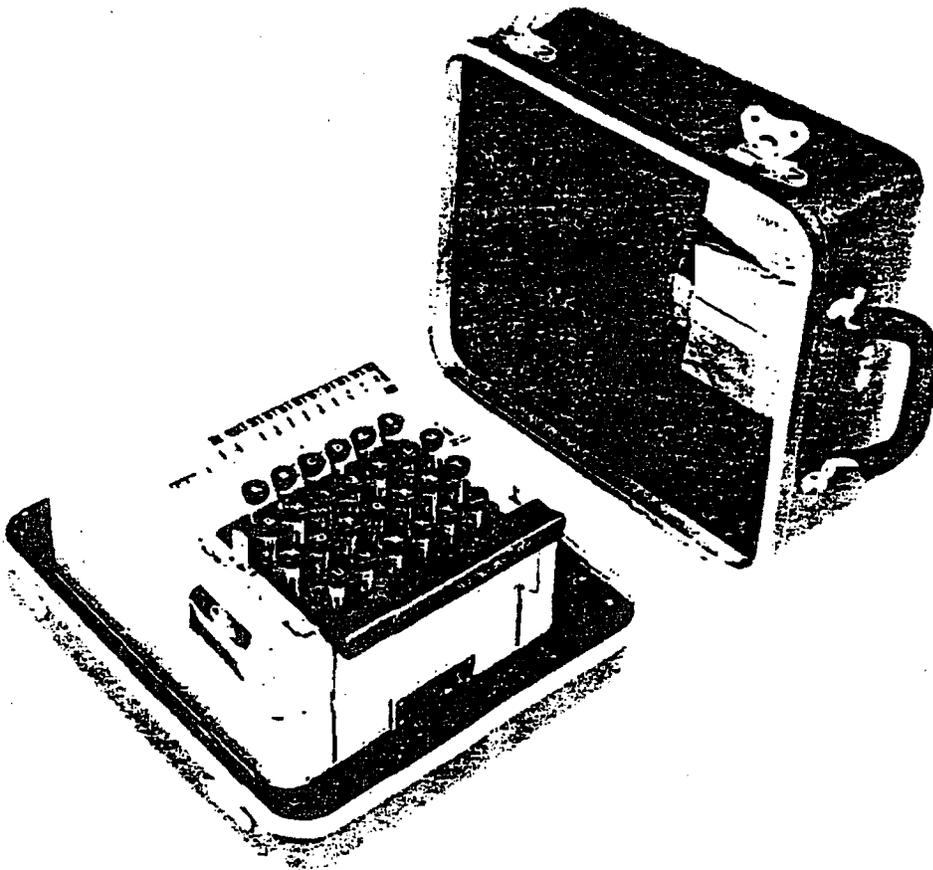
The first flop I want to talk about—rest its soul—was called the KL-17. By 1948, long before this Agency had been formed, the Signal Corps was seeking a small, light, literal cipher machine that would have good security, would require no electrical power, and would operate substantially faster than the one major all-mechanical machine that had been used throughout World War II—the famous Hagelin machine, called the M-209 shown below:



Some of our allies, like the South Vietnamese, still use this equipment; electrical variations of it are common in a number of European, Middle Eastern, and Latin American countries. Used

Correctly it is relatively secure, but in its all-mechanical form it is extremely slow; and we once calculated that operators had something like 64 separate opportunities to make errors in the course of setting it up. So something to replace and improve on this equipment was being sought.

So one of ASA's inventive minds—a man named Albert Small—had an idea: why not use a wired rotor principle but, since the equipment had to operate without electric power, use *air* instead. And a primitive model was made; but, as you might expect, it had a host of mechanical difficulties because such a concept demands some rather refined plumbing; besides, the cryptoprinciple turned out to have weaknesses, so the first version was abandoned. This early equipment was irreverently referred to as the "BLOWHARD". But Mr. Small was tenacious: he revised his cryptoprinciple, enlarged the equipment somewhat, and again put forth proposals for an air-driven system. By this time, NSA, or rather its immediate predecessor, AFSA, was in business. This second version also failed the cryptanalytic tests and was abandoned. It was referred to as the "DIE-HARD". But this Agency agreed to pursue such a system in earnest; increased the number of pneumatic rotors, conceived a very strong cryptoprinciple for it and, working mainly with Corning Glass, developed high-precision pneumatic rotors that would really work. The technical difficulties were terrific, but the engineers overcame or nearly overcame all of them. But it took time, more than five years, before we had a modest batch of KL-17's for the Services to test. The Services, principally the Army, had estimated that they would need about 20,000 of these machines, if they proved satisfactory and not too costly; and this was the incentive for the considerable R&D investment we made. We called it the "RESURRECTION." So, in 1957 we offered this:



Not bad, huh? Light (12 pounds); compact (.75 cu ft); a good deal faster and a good deal more secure than the M-209; a keyboard instead of wheel; a few minutes instead of about a half-hour to set it up for the day; and for the first (and next to last) time, a means for changing the way the machine itself works—a special variability—in the event a copy is lost. And finally, except for those rotors, almost all of its parts could be stamped out rather than machined, with the result that if it were bought in quantity, it would be inexpensive—something like \$500 each; about a third the cost of anything remotely comparable to what we had to offer. So what happened?

The first thing that happened was *time*. About ten years had passed between the expression of a requirement and the production of something that the cryptographers were willing to offer. Notions of warfare had changed drastically. It would be nuclear holocaust or nothing. "Conventional" or even "unconventional" warfare was not likely. From the communications and communications security view points, strategic, high-capacity, electronic systems supporting nuclear strategic striking forces were the things that really mattered, and the notion of ground troops dispersed to an extent where they had no access to power and communications facilities that would accommodate electrically driven cryptomachines was discredited.

None the less, the Army, the big potential customer, dutifully tested the equipment when they finally got it. They used the standard test procedure of measuring the performance of the equipment against an existing alternative system, in this case, the M-209—and found it superior in virtually every way. The equipment came out, technically, with fewer deficiencies cited in the test report than *any* other equipment this Agency had thus far submitted for test. The kinds of deficiencies were mainly in environmental situations which had not been visualized when it was built—e.g., the pneumatic system got unreliable when they took it up past something like 15,000 feet where the air is thin; and operators had difficulty with the keyboard in Arctic conditions.

But, in their conclusions, the Test Board got to the heart of the matter: they said the current Army concept of operations would permit power to be available at the lowest echelons where secure communications would be needed: and at those echelons, electrically powered crypto-equipment would be used—e.g., the KL-7 which, by then, they were using in quantity. Well, that pretty nearly killed the KL-17. Because of our pride of authorship, because we'd put lots of man years and dollars into its development, we made a reclama, in which we suggested that there were about seven requirements that the KL-17 could meet more efficiently and economically than electrically powered equipment—notably for the replacement of a large number of code systems—and requested the Army to reconsider. In due course, the Army responded: "We have reconsidered and have determined that there is no Army requirement for the KL-17." And the KL-17 was dead. So chalk up one museum piece.

Now, the KL-17 I've been talking about was a development effort in response to rather formally stated requirements—Military Characteristics (MC's, we call them) had been developed, jointly agreed, and all the essential features the system was to have had were specified for us by the potential customers; we failed because we couldn't meet the need in time and, perhaps, because neither we nor our customers had really thought through the requirement so that when the system met the last and most acid test, the commitment of funds for production in quantity (and about 10 million dollars would have been involved), enthusiasm waned.

Now, I want to talk about an "almost" system that came about in another way. As I have mentioned, we sometimes build experimental equipments not in response to formally stated requirements, but rather *in anticipation* of them. We see, or think we see, a need that the Services or other customers have not yet expressed, and rather than wait for the long formal process to be completed, we build a prototype system based on our perception of gaps in the COMSEC inventory and informal expressions of "interest" by engineers, communicators, and COMSEC planners. Such was the case in the late 50's when it seemed that there was a crying need for improved *off-line* teletypewriter security. All we had were the one-time tape systems, a rapidly aging trouble-maker called the KW-9, and an even more ancient machine called the two-dash-one for *off-line* telegraphy. (The great KW-26, you will remember, is on-line and point-to-point.) Relatively efficient and compact means for embodying key generator principles were available to us by then and had been

oved in a number of machines. It seemed to us that we could answer the communicator's prayer with an off-line machine that would solve most of the problems that plagued its predecessors. We could easily make it go as fast as any teleprinter that might come along—100,200,250,600 wpm? You name it, this machine could hack it. How about multiplicity of holders on the same key? Heretofore possible only with the lumbering electromechanical rotor techniques embodied in the KW-9. The new machine—the KW-3—could do it. How about a rapid way to key the equipment? We could do it. How about frills—adaptors so that the cipher text was produced in five-letter groups to facilitate its transmission where teletypewriter circuits were unavailable or unreliable? Could do. How about a way to take the transmission when received and automatically and instantly decipher it, so that the equipment would act as if it were on-line at the receive end? The machine could do it—it would read the indicator of the incoming message, set itself up accordingly, and automatically decipher—so no time attributable to cryptography was lost.

Sounds like it couldn't miss. The system had high security, had all these desirable operational features, was packaged in a pretty console, and worked just fine. But nobody bought it. Why not? Again, it was a combination of things. This time, time was not the problem; this one was ready before they really asked for it, not ten years later. But the customers had asked for other TTY encryption equipment which was being developed at the same time. Concepts were evolving which would minimize the need for and use of any off-line teletypewriter system. More and more, the users were accepting the notion of integrating cryptography with their communications systems, rather than accomplishing the job in two separate steps. So, with finite budgets, they hoped for smaller equipments with multi-holder rotor TTY systems in the interim. Some lessons begin to emerge from an examination of just these two aborted developments; but before summarizing them, let's talk about a few more.

While the KW-3 was gasping out its last breath, we were engaged in a frontal attack on the Department of State which, for decades, had been insisting on the continued use of certain rotor machines which, for a variety of reasons, were not adequately secure, especially in the very exposed environments where they must habitually operate. Finally, we virtually demanded that they retire some of these equipments, and they retaliated by saying they'd be glad to if we would build a new equipment tailored to their peculiar needs. They described such a system to us, and in less than 18 months, flop number three—the KW-1—was produced. (600 wpm!) This was a cipher-text auto-key system which, you will remember has the one operational flaw of exaggerating any transmission garble that occurs,—typically, in teletypewriter operations, causing 10 or 15 characters to be unreadable when a single error in transmission occurs. We had been assured that, generally, highly reliable communications circuits could be used and thought that these "extended garbles" could be tolerated on the few bad circuits that might be used.

25X3, E.O.13526

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50 U.S.C. 3605 (P.L. 86-36)

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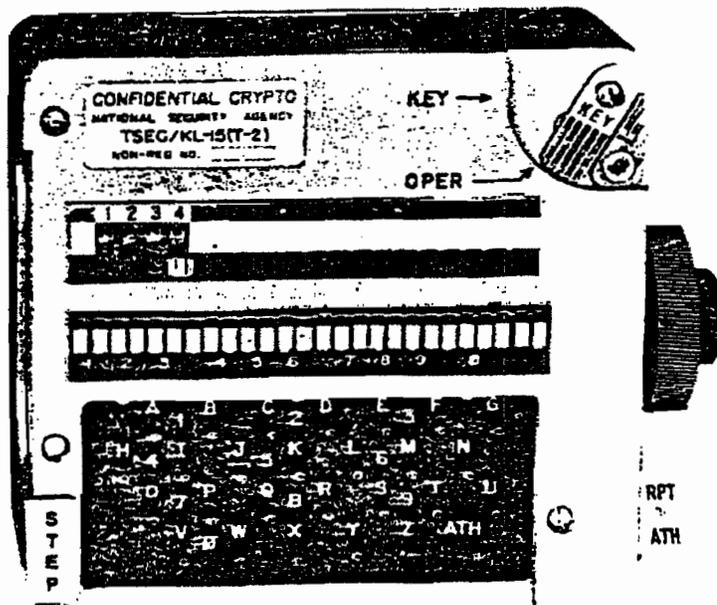
I can dispatch rather briefly another category of equipments that never saw daylight—there were the KX systems; “X” standing for “fax” or facsimile. We had a KX-3, a KX-4, and a KX-5, none of which saw appreciable use. As I have mentioned, it seems that facsimile requirements, at least during the middle and late 50’s, had a habit of evaporating each time an equipment that could do the job became available. Such small requirements as there were were picked up by other equipments—the multi-purpose kind—that were in being anyhow, such as the KO-6 and the Navy’s AFSAX-500.

So far, our failures have been a matter of time, or lack of a solid requirement, or some tragic operational flaw, or some change in concept. A much more significant and painful set of failures relates to some of the efforts we have made which collapsed because we were technically unable to accomplish what was needed. The most notable case of this has been in the voice security field. For narrow-band, long-haul voice communications, those equipments we have managed to build have gotten pretty good use—can anyone name them? (KO-6, KY-9, and KG-13/HY-2.) I know of no serious NSA attempts in the narrow-band ciphony area—i.e., ideas that got to the hardware stage, that did not go into production. USAF did have grand plans for a multi-purpose system for use in communicating with long-range aircraft—called QUICKSILVER—that would include secure voice capability. It did not pan out because the technical problems could not be surmounted at reasonable cost. But, in broad-band, short-range tactical ciphony, NSA did make two efforts that reached hardware, but failed. The first was called the AFSAY-D-803: it was the rare, perhaps unique, case in which the flop occurred because the *cryptoprinciple* was not good enough, and we did not fully appreciate this dismaying fact until after the machine was made. Naturally, the customer wanted to use it anyway; but we were adamant and had the few dozen models that had been produced dumped in the ocean.

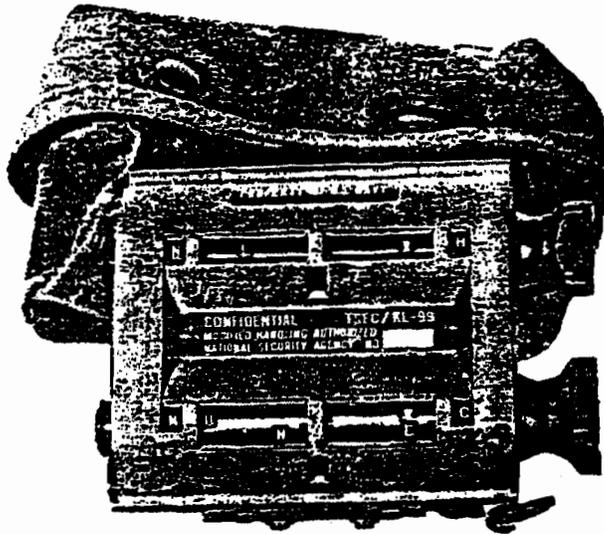
The other attempt was the famous KY-4. It was being built at about the same time as the KY-8; but while the KY-8 was designed for use in aircraft, the KY-4 was to have been used on the ground at tactical echelons, mounted on jeeps, in tanks, and what have you. It was smaller than a bread-box (if you like big bread) 9 x 11 x 13 inches; 35 pounds, ruggedized, and designed to be compatible with field radio sets of various kinds. We had fairly high hopes for it even though speech quality was poor both because we used few digits to describe it and because it was a cipher-text auto-key system, once again exaggerating all transmission garbles. By our modern standards, it did not afford very high security, and the very liberal physical security rules we imposed to facilitate its use in the field anticipated by some years the policies we have now adopted for equipments such as the KY-8 and KW-7. There were a number of things the Services did not like about the equipment; the one that killed it was probably the fact that it reduced the range of the associated radio sets; and from this rejection, a very important lesson emerges again—there will always be a very

gh resistance to any cryptosystem which reduces the communicator's ability to do his job—sometimes it's a matter of time, as in the case of off-line systems; sometimes a matter of flexibility as in the case of systems which are hard or impossible to net; sometimes it's reliability as in the case of systems that compound garbles. In this case, the user was already unhappy at the range limitations of his radios and any further reduction in the ability of the commander to reach his troops was intolerable. The possibility of modifying the contemporaneous KY-8 to meet the ground needs made the death of KY-4 easier to bear and, ironically, it has turned out that the KY-8 has thus far been bought, principally by the Army and Marines for ground use, and not for the aircraft for which it was originally designed. In future courses, you will hear about follow-on equipments like the KY-28 to relieve the airborne problem.

The last equipment to come to a bitter end is the KL-15. Here it is:



It's a nice compact toy, and it was many years abuilding. It's now headed for the museum. What was it for? It was the closest we could come to a pocket-sized machine with which we could authenticate, or perhaps encrypt call signs, or use for the encryption of short tactical messages. You'll note it has a keyboard of sorts; has self-contained power, and enough rotors and things inside it to make you think it could provide considerable security. Only one other equipment had been built in the last 10 years approaching this size; it was strictly for authentication and, although we built hundreds of them, it never got popular. Here it is, the KL-99: for some reason nicknamed the "double hot-dawg".



Well, back to the KL-15: there were forecasts of requirements for many thousands of these things (51,908)! We hoped to replace awkward, slow paper codes and authentication systems with it and get a much higher degree of security than the paper systems were providing. As a concession, we established procedures to permit encryption of short messages, as I said, although that was not the original intention. What happened? My guess is that we here in NSA had developed a kind of *security blind-spot*. (Another lesson.) The Office of Standards and Evaluations more than anybody else—and perhaps exclusively—has to shoulder the blame. Preoccupied with the fact that we are in the communications *security* business, and offered a mechanical way to encrypt short messages at tactical echelons with much higher security than existing materials could provide, we went overboard, that's all. We maximized its security advantages in our minds, minimized its operational disadvantages, and professed shock when actual service tests produced a jaundiced reaction which, had we thought it through, we might well have predicted 6 or 7 years before when we first got serious about having it built. It doesn't work any faster than a code, and not as fast as some of them. It's more difficult to use than a printed authenticator table. It's heavy. It's expensive; especially when you're buying an operating speed of only four words a minute. We had a counter on an early version. In informal user trials, they suggested it was superfluous and we'd save some money, weight, and complication if we took it off, so we did. The lack of that counter in the final "acceptance" models may have been the last straw. Without it, the user cannot keep track of where he is in enciphering or deciphering; and once he loses his place, he might as well start from the beginning again. Visualize that problem in a rainy foxhole as you try to call for support or instructions in a rapidly developing tactical situation! The lesson: the customer, particularly at tactical echelons, is not likely to be grateful or even impressed by any offer of added security if what you offer him works no better than what he already has. And he shouldn't be. Real-time communications are becoming more and more critical to our people in the field as they cope with or themselves use modern weapons systems. An authenticating pilot now may travel many miles in the time it takes him to derive a correct authenticator from a little printed chart or matrix. If you give him a machine that takes just as long and requires him to use both hands as well, you have not improved his situation.

Before we leave the subject of flops, I'd like to tell you, in case you haven't already guessed, that mistakes are not the private property of the cipher machinery—the administrative machinery also owns a few acres.

In late 1970, we found ourselves with about \$70,000,000 invested in more than 10,000 secure tactical voice equipments in Southeast Asia. These equipments—the KY-8/28/38 NESTOR family—

are sent in record time after an all out effort. There was only problem; most of them could not be used. Because of logistical and administrative errors; equipment was arriving without interconnecting cables, sometimes missing installation kits, occasionally without the correct chassis and often with no radio to match. After sorting out these problems (when they could be sorted out), next came the modifications. The following extract from a report on the subject indicates the kinds of problems we had in this area: "Since much of the communications in SEA are air-to-ground, timing of modifications was very critical. Invariably some air frames were modified, but the radios were not or vice versa. In some cases, those who had all modifications installed had no KY-8/28/38's." To top it off, even when equipments were installed, modified and operating properly, users still couldn't communicate all the time because the users weren't holding a common key.

Enough said.

I have touched on a few false starts out of a great many we have had. Those I have described got farther along than they should have. Many other attempts have been abandoned before they cost us very much. None of these efforts were total losses; each contributed to our knowledge. We do learn, although slowly.

NINTH LECTURE:

Strengths and Weaknesses

When this course was being outlined, it was suggested that an overview of the strengths and weaknesses of the U.S. COMSEC effort might be useful: but developing a generalized estimate of this kind is no simple matter. I have chosen to divide this part of the presentation into two parts—one related to the systems—and especially the machines—we now have in being; the other to our program as a whole.

As we speak of the systems themselves, you must remember that we are talking about perhaps 75 quite different animals—including more than 30 machines—each in some way unique in how it works and where it is employed. This multiplicity of systems itself implies certain strengths in our COMSEC posture: it shows that we can afford to tailor systems to specific needs and thus approach optimum efficiency and security on specific circuits or networks. By doing this, we face the hostile cryptanalysts with a variety of separate problems of diagnosis and actual attack so that he must dilute his resources so, if he concentrates on only one or a few of our systems, the balance get off light. This great diversity in our COMSEC inventory also implies certain weaknesses which I have touched on lightly once before—the lack of standardization with all its attendant ills. Complicated logistics, production difficulties, training problems for maintenance and operating personnel, unwieldy systems management—all adding to the cost and detracting from the efficiency of our program as a whole. As I said on the first day, throughout your professional life here, you will be continually weighing these contradictory factors, making “trade-offs” or compromises between optimum security and operational suitability on the one hand, and on producibility and logistic “supportability” on the other. The most secure machine in the world does the user no good if we can't make and supply the tricky components needed to keep it working. Conversely, a system which is the logistician's dream buys us nothing if essential security features or operational characteristics had to be eliminated to simplify production and supply.

You will recall that in a previous lecture, I identified for you the *major* machines in our current inventory. There are now nine of them: for literal traffic, the KL-7 and KL-47; for point-to-point teletypewriter traffic, the KW-26; for multi-holder and tactical teletypewriter traffic, the KW-7; for broadcast teletypewriter traffic, the KW-37; for long-range ciphony, the KY-9 and KG-13/HY-2; for short-range fixed plant ciphony, the KY-3; for tactical ciphony, the KY-8; and for multi-purpose key generating, the KG-3/13. These nine machines will account for about 100,000 equipments out of a total of perhaps 140 thousand. To estimate the overall strength of these systems, we have always to consider them in terms of what each is supposed to do—just what kind of traffic is it designed to protect, and for how long. Is it enciphering a routine D/F report, or a nuclear strike plan? Six factors have to be considered in the case of equipments, five in the case of manual materials:

1. The cryptoprinciple itself.
2. The embodiment of the principle in a machine or on paper.
3. The operational circumstances of use.
4. Transmission security.
5. The physical protection afforded.
6. TEMPEST (if the system is mechanical, electro-mechanical or electronic). TEMPEST will be the subject of the next lecture.

I have touched on most of these factors from time to time throughout these lectures, and will now expand on each in somewhat greater detail. In these comments, I will be generalizing about the major machines rather than codes or things unless I specify otherwise.

Cryptoprinciples.—The first thing important to understand about the principles we use is that they are designed to meet a specific set of standards. For the high-grade, long-term security systems, these standards are rigorous and conservative.

25X3, E.O.13526

25X3, E.O.13526

Withheld from public release under
§6 of the National Security Act of 1959,
50 U.S.C. 3605 (P.L. 86-36)

Embodiment.—In the late 1950's early models of the KY-8 were going through their paces, tests were being made to see how they affected associated radio sets, officials of the Services and other Agencies were attending demonstrations. An aircraft equipped with a KY-8 flew concentric circles around Andrews AFB while interested parties crowded around an equipment on the ground and listened on a loudspeaker as the pilot originated transmission after transmission and came in loud and clear until he proceeded out beyond the radio horizon. There was not a single failure to achieve

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synchrony: the potential customers were impressed and we were delighted. As I may have mentioned, the KY-8 is one of those systems that generates a new unique indicator for itself each time an originator pushes to talk. This indicator comes from a *randomizer* that puts out a stream of pulses which set up all receiving machines to a unique setting for the decryption of the message arriving a few milliseconds later.

When the engineers got the pair of equipments back in the lab, they continued using them for a series of tests and experiments for another week or so before they began to wonder about the continued infallibility of the indicator process, and decided to display the output of the randomizer on an oscilloscope. They activated the equipment and out went the "random" indicator. It was:

1111111111111111

Again: 1111111111111111

And so forth. *every* time. In short, this magnificent little equipment, costing thousands of dollars, containing something like 450 sub-miniature tubes and all sorts of complex circuitry, was producing a mono-alphabetic substitution system having considerably less resistance to cryptanalysis than many of the systems provided on the back of Kellogg's Corn Flakes packages. And thereby hangs a tale. In that fine machine, one tiny component had failed and had rendered it literally worse than useless. For the user had no way of knowing his system was not working properly—there was no alarm; there was no convenient check-point so that the situation could be detected in preventive maintenance; it did not cause any garbles in the receiving machines; they received a sequence of digits at the proper time and of proper length and, with the typical stupid indifference of machines, accepted 1111111111111111 as just as good a place to start as any other.

Of course, the cryptanalysts and engineers had been concerned with various kinds of machine failures for many years and, especially in the larger equipments, had incorporated at least rudimentary checks and alarms to catch the more likely and important failures. As far back as WW II, some of the old rotor machines had interlocks on them which would stop the machine cold if a particular rotor failed to move during 26 consecutive operations of the equipment. But, perhaps as much as any other incident—and there were lots of them—the KY-8 case triggered a full-scale and continuing pre-occupation with the science of "failure analysis". As a matter of course, the cryptanalysts, working with the engineers, must now consider the likelihood of deterioration or failure of various components and determine what the impact of such failure will be on the system. And this impact may vary widely—from catastrophic proportions to a slight reduction in the amount of work necessary for successful cryptanalysis. And based on these judgements, the kinds of safeguards incorporated may vary from that triple key generator in the KW-37 to practically nothing at all.

A modest body of doctrine has begun to evolve with respect to machine failures and what to do about them. Clearly, we cannot afford to incorporate a special safeguard for every conceivable failure—it's too costly; the resultant machinery may be too large or complicated for its intended use; there comes a point when the alarm circuits themselves cause failure, or are so complex as to comprise a maintenance man's nightmare. Those of you who get very deeply involved in this problem will become familiar with what the engineers term "mean time between failure" (MTBF). This relates to how long a given component like a diode or resistor may be expected to last. Some engineers have made calculations for whole machines and suggest a very strong correlation between the gross number of components used and the time when failure is apt to occur—the more components there are, the sooner one of them is likely to let go. Thus, the inclusion of many alarms may tend to be self-defeating, or so they argue. We argue back.

Looked at another way: S3 produces one-time tapes and alternately boasts and laments the fact that they carry out some 64 separate electronic and visual checks on their product. Still, some of them get out that shouldn't have. So, again, we are faced with judgements on how far to go without overdesigning our machinery and yet assure essential safeguards for most of our traffic most of the time. In any event, the main "rules" that have emerged are these:

1. Where very great reliability is essential to having the system be effective at all, we'll go all out to get it. Usually, this is done in one of two ways: excruciating quality control, involving hand-

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cking of components and exhaustive testing of each (e.g., the cryptocomponents in satellites); or, heavy reliance on alarms, and pre-operational checks, usually coupled with some redundancy (e.g., the KW-37 transmitter).

Note: The overriding consideration here is *not* security, but operational necessity.

2. If the failure causes the machine to stop operating all together, don't alarm it: that's plenty of alarm in itself and, if you transmit nothing, the security implications are nil.

3. If the failure is immediately obvious to the recipient, and he has a means of telling you so, e.g., by "breaking" you to stop you automatically, or by telling you "I can't understand a word you say," then, *usually*, special alarms are not necessary. (I say "usually", because in some of the systems that operate very fast, producing thousands or even millions of bits of key each second, a few moments of faulty operation might conceivably produce enough data to give the hostile analyst all he needs to exploit that failure, and a warning from the distant end may be too late to prevent attack. Even though you correct the situation, he may still have a basis for recovering all the traffic in the day's key that had been sent before the failure occurred.)

4. Don't demand special alarms based on the effect of two or more independent failures occurring simultaneously. Typically, the analyst might say: "Good lord, if that one little adder fails, the final key to be combined with the cipher text will be all 0's." And the engineer (or budgeteer) may rejoine: "But that's exactly what this little counter is designed to detect, and if it sees all 0's for more than X milliseconds, the machine will stop." If the analyst says, "But what if the counter fails, too?" he will probably lose the argument. He'd lose it, that is, if there is any reasonable way to periodically check that the counter is operative.

In translating a cryptoprinciple into hardware, there's more to it than assuring reliability, of course. There's the matter of assuring that each of the hundreds or thousands of individual elements produces the value or contributes to the process in just the way the logical design says it would. Remember I said that given *everything* about the machine, including its specific key for day, the output has to be perfectly predictable, so that other machines can produce exactly the same thing and thus communicate. This means that a crypto-mathematician or engineer ought be able to make a "paper" model of the machine and, for a particular setting write out what the final generated key should be. We had a scare here some years ago—I have forgotten with which machine: it may have been KW-37—when we finally got the first brand new production model in the laboratory and tried to check its actual key against the theoretical product. The machine seemed to work just fine, but persistently produced different key than we said it would. It took many weeks to discover that an error had been made in its fabrication: one tiny element was inverted and gave us 0's instead of 1's and vice versa.

25X3, E.O.13526

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One difficulty, not just with randomizers, but with other components as well, is in detecting some of the minor failures which cannot be practicably alarmed. In modern electronic key generators, it takes a highly trained maintenance man to note them. His maintenance manuals call for reports of various noted conditions, but in practice we have rarely seen such reports and are somewhat skeptical that the equipments are all behaving as nicely as this lack of reports would imply. We think this is partly due to the inadequacies in the reporting system itself, and partly because detection is so difficult—particularly when the weakness is one that does not stop the machine from working. So, while our current systems are rather well protected against catastrophic failure, we have to chalk up as less than satisfactory our ability to detect the creeping insidious failures in some machines.

Circumstances of Use.—After the principles themselves and their embodiment, the third factor we must consider in judging the degree of security our systems afford has to do with how they are used. In an off-line system, we may use very few internal checks on proper operation of the machine itself because operators should adhere to the general rules of complete check decryption on a separate machine before they release their cipher texts for transmission. If there was something wrong with the first machine, the second machine will surely catch it unless it happened to suffer the same failure at the same point in the process. The trouble is, off-line operations are slow enough already, without doubling message preparation time by duplicating the whole business so, now we no longer require check decryption but suggest it be adopted as an optional procedure.

A few minutes ago, I said we sometimes economized on alarms when, in on-line operations, the distant station has the opportunity to tell you you're going wrong. With a system like the KW-7, for instance, your addressee is not apt to let you produce very much gibberish before he calls you about it. But on some circuits, users may desire to use what they call "unattended operation". In this case, the machines may be left alone for some hours or even all night. Then, if something goes wrong we may lose a whole batch of traffic instead of fragmentary information or, conceivably, may have produced enough faulty key to provide an entering wedge for a cryptanalytic attack on the daily setup of the machine itself thus jeopardizing the traffic of the whole network instead of the output of a single station. So again, our security judgements about the KW-7 can't be absolute. As often as not, our security assessments of various systems will contain careful little "System X, operating properly and properly used, provides a high degree. . ."

Despite what I've implied about potential weaknesses in our machines because of shortcuts in the embodiment of principles or some tolerated peculiar circumstances of use, we have not had, in recent years, an occurrence reported which has caused us to declare, for *cryptographic* reasons, a compromise of a day's traffic in a machine system. We *have* lost a good many individual messages, and fragments of many others, because a machine has failed or an operator has erred; but even in these instances, the most usual situation is that the operator has failed to use the machine altogether and has inadvertently sent the message out in the clear.

With our codes, it is quite a different story. The circumstances of their use are the most critical factor in determining how much security they actually afford. You will recall my having said that the non-one-time codes are as a class the weakest things we have anyhow. If volume, message lengths, stereotypes, or spelling is excessive, they may collapse even more quickly than we expect them to and not give even the few days' or weeks' security for which they are typically designed. This question of how a system looks as actually used leads us to the next factor, Transmission Security for, inevitably, TRANSEC people have to find ways of examining systems as they operate, of *monitoring* and analyzing transmissions in the real world.

Transmission Security.—Traditionally, we have thought of transmission security as any and all the measures we take to prevent exploitation of our communications by any means *except* cryptanalysis. Over the years, the U.S. has managed to preserve a pretty sorry TRANSEC posture, and the exception of the one technique called Traffic Flow Security (which I described when we discussed one-time tape systems) we have very few sophisticated means in being to limit the amount and kind of information that can be derived by a mere examination of those parts of our transmissions which are not encrypted. The greatest transmission security weakness of all, of course, results from our need to transmit a great deal of information in the clear; so that hostile SIGINT has a ball in the business of examining "message externals" when the whole darned transmission is external.

What we need, of course, are more and better systems to reduce, and reduce sharply, the amount of information we now send in the clear. After that, we need a whole series of new transmission systems which will make our traffic difficult to intercept. We have a few experimental systems and one operational one that are designed to provide this resistance to interception, but a great deal of our current traffic is there for the taking so that hostile interceptors, by relatively quick and simple traffic analysis, can discover who's talking, who's being addressed, how much traffic is being exchanged and often, because of plain-language transmissions and other collateral, what's being talked about.

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Thus we hand him on a platter our order of battle and tip him off about impending plans and activities—in short, warn him about what we may be up to, and when, and where, and with what force.

One of our means of getting insights into the operations of hostile SIGINT is through interrogations of individuals who have defected from the Soviet Bloc.

25X3, E.O.13526

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Of the nine major equipments I listed for you, only three have a built-in TRANSEC feature. They are the KW-26, the KW-37, and the KG-3/13. The technique used is the Traffic Flow Security I mentioned. Once they get set up for the day, they send out a continuous flow of cipher text whether actual messages are being sent or not. So the interceptor cannot tell how many messages are being sent or whether, in fact, there is any bona fide traffic being passed. The rest of the systems, to greater or lesser degrees, are vulnerable to traffic analysis. They may encrypt the actual identities of addressees (a technique called CODRESS), but usually call signs or external groups called routing indicators give a pretty good clue as to where they're going.

So now, in our list of factors to be considered in judging current COMSEC strengths and weaknesses; chalk up TRANSEC as pretty bad.

Physical Security.—My remarks will be relatively brief. Perhaps the scope of the problem can best be illustrated by some capsule case histories from our files:

A B-52 crashes in Spain, and for weeks thereafter men sweep the area with scintillators and Geiger counters for fragments of nuclear warhead. Also scattered about are some codes and authenticators used by many aircraft in SAC. A physical security problem.

An Army unit in Seoul is overwhelmed by a horde of North Koreans and Chinese and leaves behind partly smashed, partly burned cipher machines and rotors.

A mob storms the embassy in Taiwan; breaks through the flimsy wall into the cryptocenter, and scales 100 rotors out the window to their friends below.

A Service cryptographer, badly in debt, troubles at home, etc., etc., approaches (or is approached by) a foreign agent. Crypto-documents for sale?

An operational concept for IFF (identification friend or foe) calls for 20,000 aircraft to carry identical key (remember our remarks on compartmentation?) and use it for three days or a week without change (and our comments on supersession?).

A tailgate flies open on a registered mail truck and a thousand documents are scattered along a windy highway.

A man buys fish and chips in Hong Kong and finds it wrapped in a copy of a U.S. code instead of the traditional newspaper.

A U.S. ranger outfit finds pages of a one-time pad being used as trail-markers by the Viet Cong.

A faulty incinerator belches chunks of superseded key lists and codes—as big as your fist—all over Arlington, Va.

And day after day, cryptographers reach for a key list or a key card to set up a machine, or to check it off on inventory, and it's missing. Presumed inadvertently burned.

We handle hundreds of cases annually—two or three each year are apt to be quite dramatic. The problems are knotty and seemingly infinite in their variety; they are present from the cradle to the grave in the life of a classified cryptodocument or machine. How do you produce it? How do you mark it or otherwise identify it? What degree of integrity do you demand for personnel having access to it? Is a background investigation any good? (The French, I'm told, don't clear people until they're at least 25 years old on the theory that an individual hasn't had time to develop a background good or ill until then. The Turks don't "clear" their people at all. If they prove treacherous, they shoot'em.)

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Because of all these problems, our estimate of physical security strengths and weaknesses of current systems has to be relative, just as it is in considering operational circumstances in use. You have to identify which machinery or which cryptographic network you are talking about before a meaningful statement about physical integrity can be made, for this depends on the way the material is packaged, where it's located, how big a network is involved, the level of clearance of users, and so forth. The KY-9 and KY-3, for instance, are designed for use outside of cryptocenters and communications centers in places where there are no trained guards and cryptocustodians or any set of formal controls in force. They go up into normal government office spaces and, in the case of the KY-3, into private residences. Thus, there are special problems in protecting the equipment and its keys. So those machines are packaged in a three-combination safe and we feel better. But not much better, because they aren't very good safes—some of our physical security experts refer to them, not very affectionately, as "sardine cans". But then again, *none* of the safes we can afford to make or buy are very good; they may resist covert penetration for an hour or so but that's all. So we use an important concept called "defense in depth". We use the safe as a deterrent should someone have access. We limit the time the system can be left in an unattended office or home, thus limiting opportunity for a penetration attempt. We sharply limit the amount of key that can be kept with the machine, thus minimizing how much can be lost should that shadowy "unauthorized person" get to it.

If I have to *generalize* on our current physical security posture, I would say it is "good". Not *excellent*, mind you, or we would have fewer of the cases both routine and extraordinary that we have to handle every year. But not *bad*, either, because our known and presumed losses continue to represent a very tiny fragment of the whole, and the exploitation of even those requires a good deal more than mere acquisition of the key list or what have you. Like, man, you have to get that key to somebody who understands it and knows what to do with it. (In the case of the machines left in Seoul, they were still piled up behind the signals center three days later when we re-occupied that sector, apparently undisturbed, although the N. Koreans had obviously picked over the area for things they could use, like ammunition.) Not only do you have to get the material to some SIGINT outfit, you have to get it to them *in time* to do them some good. The bulk of material we physically lose is tactical in nature; intelligence committed to such materials is almost always perishable, of no use within a few days or weeks after it is effective. And of course, the hostile SIGINT organization must have had the foresight to collect the cipher traffic in the key that is captured. It's a rather expensive investment to intercept traffic in the hope that its key will blow off a flightdeck and be recovered in time to do some good.

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TENTH LECTURE:

TEMPEST

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In 1962, an officer assigned to a very small intelligence detachment in Japan was performing the routine duty of inspecting the area around his little cryptocenter. As required he was examining a zone 200 ft. in radius to see if there was any "clandestine technical surveillance". Across the street, perhaps a hundred feet away, was a hospital controlled by the Japanese government. He sauntered past a kind of carport jutting out from one side of the building and, up under the eaves, noticed a peculiar thing—a carefully concealed dipole antenna, horizontally polarized, with wires leading through the solid cinderblock wall to which the carport abutted. He moseyed back to his headquarters, then quickly notified the counter-intelligence people and fired off a report of this "find" to Army Security Agency, who, in turn, notified NSA. He was directed to examine this antenna in detail and perhaps recover it, but although the CIC had attempted to keep the carport under surveillance that night, the antenna had mysteriously disappeared when they checked the next day. Up on the roof of the hospital was a forest of Yagi's, TV-antennas, all pointing towards Tokyo in the normal fashion, except *one*. That one was aimed right at the U.S. cryptocenter.

In 1964, you will all recall, the highly publicized flap occurred when more than 40 microphones were discovered in our Embassy in Moscow. Most people were concerned about all the conversations that may have been overheard and the resultant compromise of our diplomatic plans

We were concerned with something else: what could those microphones do to the cryptomachines used there? And for what were the unpublicized gadgets also found with the microphones? Why was there a large metal grid carefully buried in the cement of the ceiling over the Department of State communications area? A grid with a wire leading off somewhere. And what was the purpose of the wire that terminated in a very fine mesh of smaller hair-like wires (Litz wire)? And, while we were at it, how did these finds relate to other mysterious finds and reports from behind the Curtain—reports dating clear back to 1953? Intriguing? I guess so. Disturbing? Very.

Why, back in 1954, when the Soviets published a rather comprehensive set of standards for the suppression of radio frequency interference, were those standards much more stringent for their teletypewriters and other communications equipment than for such things as diathermy machines, industrial motors, and the like, even though the teleprinters were much quieter in the first place?

Behind these events and questions lies a very long history beginning with the discovery of a possible threat, the slow recognition of a large number of variations of that threat and, lumbering along a few months or a few years afterwards, a set of countermeasures to reduce or eliminate each new weakness that has been revealed. I am going to devote several hours to this story, because your exposure to this problem may be only peripheral in your other courses, because it has considerable impact on most of our cryptosystems, and because we view it as the most serious technical security problem we currently face in the COMSEC world.

First, let me state the general nature of the problem as briefly as I can, then I will attempt something of a chronology for you. In brief: any time a machine is used to process classified information electrically, the various switches, contacts, relays, and other components in that machine may emit radio frequency or acoustic energy. These emissions, like tiny radio broadcasts, may radiate through free space for considerable distances—a half mile or more in some cases. Or they may be induced on nearby conductors like signal lines, power lines, telephones lines, or water pipes and be conducted along those paths for some distance—and here we may be talking of a mile or more.

When these emissions can be intercepted and recorded, it is frequently possible to analyze them and recover the intelligence that was being processed by the source equipment. The phenomenon affects not only cipher machines but *any* information-processing equipment—teleprinters, duplicating equipment, intercomms, facsimile, computers—you name it. But it has special signifi-

ance for cryptomachines because it may reveal not only the plain text of individual messages being processed, but also that carefully guarded information about the internal machine processes being governed by those precious keys of ours. Thus, conceivably, the machine could be radiating information which could lead to the reconstruction of our key lists—and that is absolutely the worst thing that can happen to us.

Now, let's go back to the beginning. During WW II, the backbone systems for Army and Navy secure TTY communications were one-time tapes and the primitive rotor key generator then called SIGTOT. Bell Telephone rented and sold the military a mixing device called a 131-B2 and this combined with tape or SIGTOT key with plain text to effect encryption. They had one of these mixers working in one of their laboratories and, quite by accident, noted that each time the machine stepped, a spike would appear on an oscilloscope in a distant part of the lab. They examined these spikes more carefully and found, to their real dismay, that they could read the plain text of the message being enciphered by the machine. Bell Telephone was kind enough to give us some of their records of those days, and the memoranda and reports of conferences that ensued after this discovery are fascinating. They had sold the equipment to the military with the assurance that it was secure, but it wasn't. The only thing they could do was to tell the Signal Corps about it, which they did. There they met the charter members of a club of skeptics (still flourishing!) which could not believe that these tiny pips could really be exploited under practical field conditions. They are alleged to have said something like: "Don't you realize there's a war on? We can't bring our cryptographic operations to a screeching halt based on a dubious and esoteric laboratory phenomenon. If this is really dangerous, prove it." The Bell engineers were placed in a building on Varick Street in New York. Across the street and about 80 feet away was Signal Corps' Varick Street cryptocenter. The Engineers recorded signals for about an hour. Three or four hours later, they produced about 75% of the plain text that was being processed—a fast performance, by the way, that has rarely been equalled. (Although, to get ahead of the story for a moment, in some circumstances nowadays, either radiated or conducted signals can be picked up, amplified, and used to drive a teleprinter directly thus printing out the compromising information in real time.)

The Signal Corps was more than somewhat shook at this display and directed Bell Labs to explore this phenomenon in depth and provide modifications to the 131-B2 mixer to suppress the danger. In a matter of six months or so, Bell Labs had identified three separate phenomena and three basic suppression measures that might be used. The first two phenomena were the space radiated and conducted signals I have described to you; the third phenomenon was magnetic fields. Maybe you remember from high school physics having to learn about left hand rule of thumb and right hand rule of thumb, and it had to do with the fact that a magnetic field is created around a wire every time current flows. Well, a prime source of radiation in an old-fashioned mixing device is a bank of magnet-actuated relays that open and close to form the elements of teletypewriter characters being processed. The magnetic fields surrounding those magnets expand and collapse each time they operate, so a proper antenna (usually some kind of loop, I think) nearby can detect each operation of each relay and thus recover the characters being processed. The bad thing about magnetic fields is that they exist in various strengths for virtually all the circuitry we use and are extremely difficult to suppress. The good thing about them is that they "attenuate" or decay rapidly. Even strong fields disappear in 30 feet or so, so they comprise a threat only in special circumstances where a hostile intercept activity can get quite close to us.

The three basic suppression measures Bell Labs suggested were:

1. Shielding (for radiation through space and magnetic fields),
2. Filtering (for conducted signals on power lines, signal lines, etc),
3. Masking (for either space radiated or conducted signals, but mostly for space).

The trouble with these solutions, whether used singly or in combination, all stems from the same thing: that is the fact that, quite typically, these compromising emanations may occur over a very large portion of the frequency spectrum, having been seen from near d.c. all the way up to the acycle range (and that's a lot of cycles). Furthermore, 5 copies of the same machine may each

exhibit different characteristics, radiating at different frequencies and with different amplitudes. And even the same machine may change from day to day as humidity changes or as contacts become pitted, or as other components age. This means that any shielding used must form an effective barrier against a large variety of signals, and this proves difficult. Similarly, the filter has to be a nearly perfect one and they become big, heavy, and expensive. Furthermore, on signal lines for example, how do you get your legitimate cipher signal through without compromising signals squeezing through with them?

Masking, which is the notion of deliberately creating a lot of ambient electrical noise to override, jam, smear out or otherwise hide the offending signals, has its problems too. It's very difficult to make a masking device which will consistently cover the whole spectrum, and the idea of deliberately generating relatively high amplitude interference does not sit too well with folks like IRAC (The Interdepartmental Radio Advisory Committee) of the Office of Telecommunications (OTP) who don't like the idea of creating herring bone patterns in nearby TV pictures or interrupting legitimate signals like aircraft beacons.

Bell Labs went ahead and modified a mixer, calling it the 131-A1. In it they used both shielding and filtering techniques. Signal Corps took one look at it and turned thumbs down. The trouble was, to contain the offending signals, Bell had to virtually encapsulate the machine. Instead of a modification kit that could be sent to the field, the machines would have to be sent back and rehabilitated. The encapsulation gave problems of heat dissipation, made maintenance extremely difficult, and hampered operations by limiting access to the various controls.

Instead of buying this monster, the Signal Corps people resorted to the only other solution they could think of. They went out and warned commanders of the problem, advised them to control a zone about 100 feet in diameter around their communications center to prevent covert interception, and let it go at that. And the cryptologic community as a whole let it go at that for the next seven years or so. The war ended; most of the people involved went back to civilian life; the files were retired, dispersed, and destroyed. The whole problem was plain forgotten. Then, in 1951, the problem was, for all practical purposes, rediscovered by CIA when they were toying with the same old 131-B2 mixer. They reported having read plain text about a quarter mile down the signal line and asked if we were interested. Of course, we were. Some power line and signal line filters were built and immediately installed on these equipments and they did the job pretty well as far as conducted signals were concerned. Space radiation continued unabated, however, and the first of many "radiation" policies was issued in the form of a letter (AFSA Serial: 000404, Nov. 1953?) to all SIGINT activities requiring them to either:

1. Control a zone 200 feet in all directions around their cryptocenters (the idea of preventing interceptors from getting close enough to detect space radiation easily), or
2. Operate at least 10 TTY devices simultaneously (the idea of masking; putting out such a profusion of signals that interception and analysis would be difficult), or
3. Get a waiver based on operational necessity.

And the SIGINT community conformed as best it could; and general service communicators adopted similar rules in some instances. The 200 feet figure, by the way, was quite arbitrary. It was not based on any empirical evidence that beyond such distance interception was impractical. Rather, it was the biggest security zone we believed the majority of stations could reasonably comply with and we knew that, with instrumentation then available, successful exploitation at that range was a darn sight more difficult than at closer distances and, in some environments not practical at all.

At the same time we were scurrying around trying to cope with the 131-B2 mixer, we thought it would be prudent to examine every other cipher machine we had to see whether the same problem existed. For, way back in the late 40's, Mr. Ryon Page and one of his people were walking past the cryptocenter at Arlington Hall and had heard the rotor machines inside clunking away. He wondered what the effect would be on the security of those systems if someone were able to determine which rotors or how many rotors were stepping during a typical encryption process. In due course, some

assessments were made on what the effect would be. The assessments concluded that it would be bad, and they were filed away for future reference. Now, it appeared that there might be a way for an interceptor to recover this kind of data. So, painstakingly, we began looking at our cryptographic inventory. Everything tested radiated and radiated rather prolifically. In examining the rotor machines, it was noted the voltage on their power lines tended to fluctuate as a function of the numbers of rotors moving, and so a fourth phenomenon, called power line modulation, was discovered through which it was possible to correlate tiny surges and drops in power with rotor motion and certain other machine functions.

Progress in examining the machines and developing suppression measures was very slow. In those days, S2 did not have any people or facilities to work on this problem; no fancy radio receivers or recording devices, no big screen rooms and other laboratory aids, and such things as we obtained we begged from the SIGINT people at Ft. Meade. In due course, they got overloaded, and they could no longer divert their SIGINT resources to our COMSEC problems. So R&D began to pick up a share of the burden, and we began to build up a capability in S2. The Services were called in, and a rudimentary joint program for investigative and corrective action got underway. The Navy, particularly, brought considerable resources to bear on the problem.

By 1955, a number of possible techniques for suppressing the phenomena had been tried: filtering techniques were refined somewhat; teletypewriter devices were modified so that all the relays operated at once so that only a single spike was produced with each character, instead of five smaller spikes representing each baud—but the size of the spike changed with each character produced and the analysts could still read it quickly. A "balanced" 10-wire system was tried which would cause each radiated signal to appear identical, but to achieve and maintain such balance proved impractical. Hydraulic techniques were tried to get away from electricity, but were abandoned as too cumbersome; experiments were made with different types of batteries and motor generators to lick the power line problem—none too successfully. The business of discovering new TEMPEST means, of refining techniques and instrumentation for detecting, recording, and analyzing these signals progressed more swiftly than the art of suppressing them. With each new trick reported to the bosses for extracting intelligence from cryptomachines and their ancillaries, the engineers and analysts got the complaint: "Why don't you guys stop going onward and upward, and try going downward and backward for a while—cure a few of the ills we already know about, instead of finding endless new ones." I guess it's a characteristic of our business that the attack is more exciting than the defense. There's something more glamorous, perhaps, about finding a way to read one of these signals a thousand miles away than to go through the plain drudgery and hard work necessary to suppress that whacking great spike first seen in 1943.

At any rate, when they turned over the next rock, they found the acoustical problem under it. Phenomenon #5. Of course, you will recall Mr. Page and his people speculating about it way back in 1949 or so, but since the electromagnetic phenomena were so much more prevalent and seemed to go so much farther, it was some years before we got around to a hard look at what sonic and ultrasonic emissions from mechanical and electromechanical machines might have in store.

We found that most acoustical emanations are difficult or impossible to exploit as soon as you place your microphonic device outside of the room in which the source equipment is located; you need a direct shot at the target machine; a piece of paper inserted between, say an offending keyboard, and the pickup device is usually enough to prevent sufficiently accurate recordings to permit exploitation. Shotgun microphones—the kind used to pick up a quarterback's signals in a huddle—and large parabolic antennas are effective at hundreds of feet if, again, you can see the equipment. But in general, the acoustical threat is confined to those installations where the covert interceptor has been able to get some kind of microphone in the same room with your information-processing device—some kind of microphone like an ordinary telephone that has been bugged or left off the hook. One interesting discovery was that, when the room is "soundproofed" with ordinary acoustical tiles, the job of exploitation is easier because the soundproofing cuts down reflected and reverberating sound, and thus provides cleaner signals. A disturbing discovery was that ordinary microphones, probably planted for the purpose of picking up conversations in a cryptocenter, could detect

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machine sounds with enough fidelity to permit exploitation. And such microphones were discovered in [redacted]

The example of an acoustical intercept I just showed you is from an actual test of the little keyboard of the KL-15. You will note that each individual key produces a unique "signature". Since (before it died) the KL-15 was expected to be used in conjunction with telephonic communications, this test was made by placing the machine a few feet from a gray phone handset at Ft. Meade and making the recording in the laboratory at Nebraska Avenue from another handset. So that's really a recording taken at a range of about 25 miles, and the signals were encrypted and decrypted in the gray phone system, to boot.

The last but not least of the TEMPEST phenomena which concerns us is referred to as cipher signal modulation or, more accurately, as cipher signal anomalies. An anomaly, as you may know, is a peculiarity or variation from the expected norm. The theory is this: suppose, when a crypto-system is hooked to a radio transmitter for on-line operation, compromising radiation or conducted signals get to the transmitter right along with the cipher text and, instead of just sending the cipher text, the transmitter picks up the little compromising emissions as well and sends them out full blast. They would then "hitchhike" on the cipher transmission, modulating the carrier, and would theoretically travel as far as the cipher text does. Alternatively, suppose the compromising emanations cause some tiny variations or irregularities in the cipher characters themselves, "modulate" them, change their shape or timing or amplitude? Then, possibly, anyone intercepting the cipher text (and anyone can) can examine the structure of the cipher signals minutely (perhaps by displaying and photographing them on the face of an oscilloscope) and correlate these irregularities or anomalies with the plain text that was being processed way back at the source of the transmission. This process is called "fine structure analysis". Clearly, if this phenomenon proves to be at all prevalent in our system, its implications for COMSEC are profound. No longer are we talking about signals which can, at best, be exploited at perhaps a mile or two away and, more likely, at a few hundred feet or less. No longer does the hostile interceptor have to engage in what is really an extremely difficult and often dangerous business, i.e., getting covertly established close to our installations, working with equipment that must be fairly small and portable so that his receivers are unlikely to be ultra-sensitive, and his recording devices far less than ideal. Rather, he may sit home in a full-scale laboratory with the most sophisticated equipment he can assemble and, with plenty of time and no danger carry out his attack. But, so far, we seem to be all right. For several years, we have had SIGINT stations collecting samples of U.S. cipher transmissions containing possible anomalies and forwarding them here for detailed examination. We have no proven case of operational traffic jeopardized this way.

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I believe we've talked enough about the difficulties we face.

In late 1956, the Navy Research Laboratory, which had been working on the problem of suppressing compromising emanations for some years, came up with the first big breakthrough in a suppression technique. The device they produced was called the NRL Keyer, and it was highly successful. After being confronted with the shortcomings of shields and filters and maskers, they said, "Can we find a way of eliminating these offending signals at their source? Instead of trying to bottle up, filter out, shield, mask, or encapsulate these signals, why not reduce their amplitudes so much that they just can't go very far in the first place? Can we make these critical components operate at one or two volts instead of 60 or 120, and use power measured in microamps instead of milliamps?" They could, and did. NSA quickly adopted this low-level keying technique and immediately produced several hundred one-time tape mixers using this circuitry, together with some nominal shielding and filtering. The equipment was tested, and components that previously radiated signals which were theoretically exploitable at a half mile or so could no longer be

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detected at all beyond 20 feet. The next equipment built, the KW-26, and every subsequent crypto-equipment produced by this Agency contained these circuits, and a great stride had been made.

But we weren't out of the woods yet: the communicators insisted that the reduced voltages would give reduced reliability in their equipments, and that while satisfactory operation could be demonstrated in a simple setup with the crypto-machine and its input-output devices located close by, if the ancillaries were placed at some distance ("remoted" they call it), or if a multiplicity of ancillaries had to be operated simultaneously from a single keyer, or if the low level signals had to be patched through various switchboard arrangements, operation would be unsatisfactory. The upshot was that in the KW-26 and a number of other NSA machines, an "option" was provided—so that either high-level radiating signals could be used or low-level keying adopted. In the end, almost all of the installations were made without full suppression. Even the CRITCOM network, the key intelligence reporting system over which NSA exercises the most technical and operational control, was engineered without full-scale, low-level keying.

The next difficulty we found in the corrective action program was the great difference in cost and efficiency between developing new relatively clean equipment by incorporating good suppression features in the basic design, and in retrofitting the tens of thousands of equipments—particularly the ancillaries such as teletypewriters—which we do not build ourselves but, rather, acquire from commercial sources. For, in addition to the need for low-level keyers, some shielding and filtering is still normally required; circuits have to be laid out very carefully with as much separation or isolation as possible between those which process plain text and those which lead to the outside world—this is the concept known as Red/Black separation, with the red circuits being those carrying classified plain text, and the other circuits being black. Finally, grounding had to be very carefully arranged, with all the red circuits sharing a common ground and with that ground isolated from any others. To accomplish this task in an already established installation is extremely difficult and costly, and I'll talk about it in more detail later when I cover the basic plans, policies, standards, and criteria which have now been adopted.

By 1958, we had enough knowledge of the problem, possible solutions in hand, and organizations embroiled to make it possible to develop some broad policies with respect to TEMPEST. The MCEB (Military Communications Electronics Board) operating under the JCS, formulated and adopted such policy—called a Joint policy because all the Services subscribed to it. It established some important points:

1. As an *objective*, the Military would not use equipment to process classified information if it radiated beyond the normal limits of physical control around a typical installation.
2. *Fifty feet* was established as the normal limit of control. The choice of this figure was somewhat arbitrary; but *some* figures had to be chosen since equipment designers needed to have some upper limit of acceptable radiation to work against.
3. NAG-1, a document produced by S2, was accepted as the standard of measurement that designers and testers were to use to determine whether the fifty-foot limit was met. This document specifies the kinds of measurements to be made, the sensitivity of the measuring instruments to be used, the specific procedures to be followed in making measurements, and the heart of the document sets forth a series of *curves* against which the equipment tester must compare his results: if these curves are exceeded, radiated signals (or conducted signals, etc.) can be expected to be detectable *beyond* 50 feet, and added suppression is necessary.
4. The classification of various aspects of the TEMPEST problem was specified.

Documents like these are important. It was more than an assembly of duck-billed platitudes; it set the course that the Military would follow, and laid the groundwork for more detailed policies which would eventually be adopted nationally. It had weaknesses, of course. It said nothing about *money*, for example; and the best intentions are meaningless without budgetary action to support them. And it set no time frame for accomplishing the objective. And it provided no priorities for action, or factors to be used in determining which equipments, systems, and installations were to be made to conform first.

The next year, 1959, the policy was adopted by the Canadians and UK, and thus became a Combined policy. This gave it a little more status, and assured that there would be a consistent planning in systems used for Combined communications. In that same year, the first National COMSEC Plan was written. In it, there was a section dealing with compromising emanations. This document was the first attempt to establish some specific responsibilities among various agencies of Government with respect to TEMPEST, and to lay out an orderly program of investigative and corrective action. Based on their capabilities and interest, six organizations were identified to carry out the bulk of the work. These were ourselves, Navy, Army, Air Force, CIA, and State. The plan also called for some central coordinating body to help manage the overall effort. It was also in this plan that, for the first time, there were really explicit statements made indicating that the TEMPEST problem was not confined to communications security equipment and its ancillaries, that it extended to any equipment used to process classified information, including computers.

And so, it was in about this time frame that the word began to leak out to people outside the COMSEC and SIGINT fields, to other agencies of government, and to the manufacturing world.

You may remember from your briefings on the overall organization of this Agency, that there is something called the U.S. Communications Security Board, and that very broad policy direction for all COMSEC matters in the government stems from the Board. It consists of a chairman from the Dept. of Defense through whom the Director, NSA reports to the Secretary of Defense, and members from NSA, Army, Navy, Air Force, State, CIA, FBI, AEC, Treasury and Transportation. This Board meets irregularly, it does its business mainly by circulating proposed policy papers among its members and having them vote for adoption. The USCSB met in 1960 to contemplate this TEMPEST problem, and established its first and only permanent committee to cope with it. This committee is referred to as SCOCE (Special Committee on Compromising Emanations) and has, to date, always been chaired by a member of the S Organization.

The ink was hardly dry on the committee's charter before it got up to its ears in difficulty. The counterpart of USCSB in the intelligence world is called USIB—the U.S. Intelligence Board. Unlike USCSB, it meets regularly and has a structure of permanent committees to work on various aspects of their business. One part of their business, of course, consists of the rapid processing, by computer techniques, of a great deal of intelligence, and they had been contemplating the adoption of some standardized input-output devices of which the archetype is an automatic electric typewriter called *Flexowriter* which can type, punch tapes or cards, and produce page copy, and which is a very strong radiator. In a rare action, the Intelligence Board appealed to the COMSEC Board for policy direction regarding the use of these devices and, of course, this was immediately turned over to the fledgling Special Committee. The committee arranged to have some Flexowriters and similar equipments tested. They were found, as a class, to be the strongest emitters of space radiation of any equipment in wide use for the processing of classified information. While, as I have mentioned, typical unsuppressed teletypewriters and mixers are ordinarily quite difficult to exploit much beyond 200 feet through free space, actual field tests to Flexowriters showed them to be readable as far out as 3,200 feet and, typically, at more than 1000 feet, even when they were operated in a very noisy electrical environment.

One such test was conducted at the Naval Security Station. (By the way, in case I haven't mentioned this already, the S Organization was located at the Naval Security Station, Washington D.C. until May 1968 when we moved here to Ft. Meade.) Mobile test equipment had been acquired, including a rolling laboratory which we refer to as "the Van". In S3, a device called *Justowriter* was being used to set up maintenance manuals. Our van started out close to the building and gathered in a great potpourri of signals emitting from the tape factory and the dozens of the machines operating in S3. As they moved out, most of the signals began to fade. But not the Justowriter. By the time they got out to the gas station on the far side of the parking lot—that's about 600 feet—most of the other signals had disappeared, but they could still read the Justowriter. They estimated that the signals were strong enough to have continued out as far as American University grounds three blocks away. (The solution in this case, was to install a shielded enclosure—a subject I will cover subsequently.)

In any event, the Committee submitted a series of recommendations to the USCSB which subsequently became known as the *Flexowriter Policy*. The Board adopted it and it upset everybody. Here's why: as the first point, the Committee recommended that the existing Flexowriters not be used to process classified information at all in any overseas environment; that it be limited to the processing of CONFIDENTIAL information in the United States, and then only if a 400-foot security zone could be maintained around it. Exceptions could be made if the equipment could be placed in an approved shielded enclosure, or as usual, if waivers based on operational necessity were granted by the heads of the departments and agencies concerned.

The Committee also recommended that both a "quick-fix" program and a long-range, corrective action program be carried out. It was recommended that the Navy be made Executive Agent to develop a new equipment which would meet the standards of NAG-1 and, grudgingly, DDR&E gave Navy some funds (about a quarter of what they asked for) to carry out that development. Meanwhile, manufacturers were coaxed to develop some interim suppression measures for their product lines, and the Committee published two lists: one containing equipments which were forbidden, the other specifying acceptable interim devices. This policy is still in force; but most users have been unable to afford the fixes, and have chosen to cease operations altogether, e.g., CIA, or to operate under waivers on a calculated risk basis, e.g., most SIGINT sites.

While the Committee was still reeling from the repercussions and recriminations for having sponsored an onerous and impractical policy which made it more difficult for operational people to do their job, it grasped an even thornier nettle. It undertook to take the old toothless Joint and Combined policies and convert them into a strong National policy which:

1. Would be binding on all departments and agencies of government, not just the military.
2. Would establish NAG-1 as a standard of acceptance for future government procurement of hardware (NAG-1, by the way, was converted to *Federal Standard*. (FS-222) to facilitate its wide distribution and use.)
3. Would establish a deadline for eliminating un-suppressed equipment from government inventories.

By now the governmental effort had changed from a haphazard, halting set of uncoordinated activities mainly aimed at cryptologic problems, to a multi-million dollar program aimed at the full range of information-processing equipment we use. Symposia had been held in Industrial forums to educate manufacturers about the nature of the problem and the Government's intentions to correct it. Work had been parcelled out to different agencies according to their areas of prime interest and competence; the SIGINT community had become interested in possibilities for gathering intelligence through TEMPEST exploitation. It, nonetheless, took the Committee two full years to complete the new National policy and coordinate it with some 22 different agencies. Before it could have any real effect it had to be *implemented*. The implementing directive—5200.19—was signed by Secretary McNamara in December, 1964. Bureaucracy is wonderful. Before its specific provisions could be carried out, the various departments and agencies had to implement the implementing directive within their own organizations. These implementing documents began dribbling in throughout 1965, and it is my sad duty to report that NSA's own implementation did not take effect until June, 1966.

All this makes the picture seem more gloomy than it is. These implementing documents are, in the final analysis, formalities. The fact of the matter is that most organizations, our own included, have been carrying out the intent of these policies to the best of our technical and budgetary abilities for some years.

While all this was going on in the policy field, much was happening in the technical area. First, let me cover the matter of shielded enclosures. To do so, I have to go back to about 1956 when the National Security Council got aroused over the irritating fact that various counter-intelligence people, particularly in the Department of State, kept stumbling across hidden microphones in their residences and offices overseas. They created a Technical Surveillance Countermeasures Committee under the Chairmanship of State and with the Services, FBI, CIA, and NSA also represented. This group was charged with finding out all they could about these listening devices,

and developing a program to counter them. In the space of a few years, they assembled information showing that nearly 500 microphones had been discovered in U.S. installations; all of them overseas, 90 % of those behind the Iron Curtain. They examined a large number of possible countermeasures, including special probes and search techniques, electronic devices to locate microphones buried in walls, and what-have-you. Each June, in their report to the NSC, they would dutifully confess that the state-of-the-art of hiding surveillance devices exceeded our ability to find them. About the only way to be sure an embassy was "clean" would be to take it apart inch-by-inch which we couldn't afford, and which might prove fruitless anyhow, since host-country labor had to be used to put it back together again. (Incidentally, years later, we began to think we had darned well better be able to afford something close to it, for we found things that had been undetected in a dozen previous inspections.)

The notion of building a complete, sound-proof, inspectable room-within-a-room evolved to provide a secure conference area for diplomats and intelligence personnel. During these years, NSA's main interest in and input to the committee had to do with the sanctity of cryptocenters in these vulnerable overseas installations, and we campaigned for rooms that would be not only sound-proof but proof against compromising electromagnetic emanations as well. State Department developed a conference room made of plastic which was dubbed the "fish-bowl" and some of them are in use behind the Curtain now. CIA made the first enclosure which was both "sound-proof" and electrically shielded. This enclosure went over like—and apparently weighed about as much as—a lead balloon. It was nicknamed the "Meat Locker" and the consensus was that nobody would consent to work in such a steel box, that they needed windows and drapes or they'd get claustrophobia or something. Ironically, though, it turned out that some of the people who were against this technique for aesthetic reasons spent their days in sub-sub basement areas with cinder-block walls and no windows within 50 yards.

The really attractive thing about the enclosures, from the security point of view, was the fact that they provided not only the best means, but the only means we had come across to provide really complete TEMPEST protection in those environments where a large-scale intercept effort could be mounted at close range. So, despite aesthetic problems, and weight, and cost, and maintenance, and enormous difficulties in installation, we campaigned very strongly for their use in what we called "critical" locations, with Moscow at the top of the list.

So again, in the matter of Standards, NSA took the lead, publishing two specifications (65-5 and 65-6) one describing "fully" shielded enclosures with both RF and acoustic protection; the other describing a cheaper enclosure providing RF protection only. And by threats, pleas, "proofs" and persuasion, we convinced the Department of State, CIA, and the Services, to procure a handful of these expensive, unwieldy screen rooms for installation in their most vulnerable facilities. One of the first, thank goodness, went into Moscow—in fact, two of them; one for the Dept. of State code room as they call it, and one for the cryptocenter used by the Military Attaches. So, when highest levels of government required us to produce damage reports on the microphone finds there, we were able with straight faces and good conscience to report that, in our best judgment, cryptographic operations were immune from exploitation—the fully shielded enclosures—were in place.

But none of us was claiming that this suppression measure was suitable for any wide-scale application—it's just too cramped, inflexible, and expensive. We have managed to have them installed not only in overseas installations where we are physically exposed but also in a few locations here at home where the information being processed is of unusual sensitivity. Thus, the Atomic Energy Commission acquired more than 50 of them to house computers and their ancillaries where a heavy volume of Restricted Data must be processed; we have one here in S3 to protect most of our key and code generation equipment—a \$134,000 investment, by the way—which you may see when you tour our production facilities. The Navy has one of comparable size at the Naval Security Station for its computers. (But they have the door open most of the time.) At Operations Building No. 1, on the other hand, we don't have one—instead, we use careful environmental controls, inspecting the whole area around the Operations Building periodically, and using mobile equipment to examine the actual radiation detectable in the area.

In about 1962, two more related aspects of the TEMPEST problem began to be fully recognized. First, there was the growing recognition of the inadequacies of suppression effort which were being made piece-meal, one equipment at a time, without relating that equipment to the complex of ancillaries and wiring in which it might work. We called this the "system" problem. We needed a way to test, evaluate, and suppress overall secure communications complexes, because radiation and conduction difficulties stem not only from the inherent characteristics of individual pieces of machinery but also from the way they are connected to other machines—the proximity and conductivity and grounding arrangements of all the associated wiring often determined whether a system as a whole was safe. And so, one of the first systems that we tried to evaluate in this way was the COMLOGNET system of the Army. This system, using the KG-13, was intended principally for handling logistics data and involved a number of switches, and data transceivers, and information storage units, and control consoles. Using the sharpest COMSEC teeth we have, our authority for reviewing and approving cryptoprinciples, and their associated rules, regulations, and procedures of use, we insisted that the system as a whole be made safe from the TEMPEST point of view before we would authorize traffic of all classifications to be processed. This brought enough pressure to bear on the system designers for them to set up a prototype complex at Ft. Monmouth and test the whole thing on the spot. They found and corrected a number of weaknesses before the "system" approval was given. A second means we have adopted, in the case of smaller systems, like a KW-7 being used with a teletypewriter and a transmitter distributor, is to pick a relatively small number of most likely configurations to be used and test each as a package. We clean up these basic packages as much as is needed and then approve them. If a user wants to use some less common arrangement of ancillaries, he must first test it. So, in the case of KW-7, we took the three most common teleprinters—the MOD-28 line of Teletype Corporation, the Kleinschmidt (an Army favorite), and the MITE teleprinter; authorized the use of any of these three combinations and provided the specific installation instructions necessary to assure that they would be radiation-free when used. We did the same thing with the little KY-8, this time listing "approved" radio sets with which it could be safely used.

Adequate systems testing for the larger complexes continues to be a problem—one with which S4, S2, DCA, and the Special Committee are all occupied.

The second and related problem that reared its head in about 1962 is the matter of RED/BLACK separation that I mentioned. Over the years, it had become increasingly evident that rather specific and detailed standards, materials, and procedures had to be used in laying out or modifying an installation if TEMPEST problems were to be avoided, and the larger the installation, the more difficult proper installation became—with switching centers perhaps the most difficult case of all. For some years, NSA has been making a really hard effort to get other organizations to display initiative and commit resources to the TEMPEST problem. We simply could not do it all ourselves. So we were pleased to cooperate with DCA when it decided to tackle the question of installation standards and criteria for the Defense Communications System (DCS). It was needed for all three Services; the Services, in fact, actually operate DCS. Virtually every strategic Department of Defense circuit is involved—more than 50,000 in all. DCA felt that this system would clearly be unmanageable unless the Services could standardize some of their equipment, communications procedures, signalling techniques, and the like. General Starbird, who directed DCA, was also convinced that TEMPEST is a serious problem, and desired the Services to use a common approach in DCS installations with respect to that problem. Thus, DCA began to write a very large installation standard comprising a number of volumes, and laying out in great detail how various circuits and equipments were to be installed. NSA personnel assisted in the technical inputs to this document called DCA Circular 175-6A. A Joint Study Group was formed under DCA chairmanship to coordinate the installation problem as well as a number of other TEMPEST tasks affecting the Defense Communications System and the National Communications System (NCS) which interconnects strategic civil organizations along with the Defense Department. In developing the installation standards, the study group and DCA took a rather hard line, and specified tough requirements for isolating all the RED circuits, equipments, and areas from the BLACK ones, i.e., assuring

physical and electrical separation between those circuits carrying classified information in the clear, and those carrying only unclassified information (like cipher signals, control signals, power, and ordinary telephone lines). In addition to shielding and filtering, this called for the use of conduits and often, in existing installations, drastic rearrangement of all the equipment and wiring was involved.

You will remember that the Department of Defense had *directed* that extensive TEMPEST corrective action be taken. I said that the Directive specified NAG-1 (FS-222) as a standard of acceptance for new equipment. It also mentioned a number of other documents as being applicable, and particularly, this very same DCA Circular I've just been describing.

As this whole program gathered steam, the monetary implications began to look staggering; the capability of the government accomplishing *all* the corrective action implied in a reasonable time seemed doubtful: furthermore, we were beginning to see that there were subtle inter-relationships between different kinds of countermeasures; and that some of these countermeasures, in particular situations, might be quite superfluous when some of the other countermeasures were rigidly applied. Remember, by now we had been telling people to shield, to filter, to place things in conduit, to ground properly, to separate circuits, to use low-level keying, to provide security zones and sometimes, to use shielded enclosures. It took us a while to realize some fairly obvious things, for example, if you have done a very good job of suppressing space radiation, you may not need very much filtering of the signal line because there's no signal to induce itself on it; or you may not need to put that line in conduit for the same reason. If you have put a line in conduit, which is a kind of shielding, then perhaps you don't have to separate it very far from other lines because the conduit itself has achieved the isolation you seek. And so forth. We had already realized that some installations, inherently, have fewer TEMPEST problems than others. The interception of space radiation from an equipment located in a missile silo or SAC's underground command center does not seem practicable; so perhaps the expensive space radiation suppressions ought not be applied there. Similarly, the suppression measures necessary in an airborne platform or in a ship at sea are quite different from those needed in a communications center in Germany.

The upshot was that, in 1965, NSA undertook to examine all the standards and techniques of suppression that had been published, to relate them to one another, and to provide some guidelines on how the security *intent* of the "national policy" and its implementing directives could be met through a judicious and *selective* application of the various suppression measures as a function of installation, environment, traffic sensitivity, and equipment being used. These guidelines were published as NSA Circular 90-9 and have been extremely well received.

In December 1970, the U.S. TEMPEST community introduced new TEMPEST laboratory test standards for non-cryptographic equipments. Test procedures for compromising acoustical and electromagnetic emanations were addressed in two separate documents. These laboratory test standards were prepared by SCOCE and superseded FS-222. They were approved by the USCSB and promulgated as Information Memoranda under the National COMSEC/EMSEC Issuance System. NACSEM 5100 is the Compromising Emanations Laboratory Test Standard for Electromagnetic Emanations and NACSEM 5103 is the Compromising Emanations Laboratory Test Standard for Acoustic Emanations. These documents are intended only to provide for standardized testing procedures among U.S. Government Departments and Agencies. They were in no way intended to establish standardized TEMPEST suppression limits for all U.S. Government Departments and Agencies. Under the terms of the USCSB's National Policy on Compromising Emanations (USCSB 4-4), U.S. Government Departments and Agencies are responsible for establishing their own TEMPEST programs to determine the degree of TEMPEST suppression which should be applied to their information-processing equipments.

In January 1971, NSA published KAG-30A/TSEC, Compromising Emanations Standard for Cryptographic Equipments. This standard represented our first effort to establish standardized testing procedures and limits for controlling the level of compromising emanations from cryptographic equipments.

DCA Circular 175-6A was superseded by DCA Circular 300-175-1 in 1969, which in turn was replaced by MIL HDBK 232 on 14 November 1972.

Before I summarize the TEMPEST situation and give you my personal conclusions about its security implications, I should make it clear that there are a number of topics in this field which comprise additional problems for us beyond those I've talked about at length. There are, for example, about a half-dozen phenomena beyond the eight I described to you; but those eight were the most important ones. I have hardly touched on the role of industry or on the program designed to train manufacturers and mobilize their resources to work on the problem. I have mentioned on-site empirical testing of operating installations only in the case of Fort Meade—actually, each of the Services has a modest capability for checking out specific installations and this “mobile test program” is a valuable asset to our work in correcting existing difficulties. For example, the Air Force, Navy, and ourselves have completed a joint survey of the whole signal environment of the island of Guam. As you know, B52 and many Navy operations stage there. As you may not know, a Soviet SIGINT trawler has loitered just off-shore for many months. Are the Soviets simply gathering plain language communications, or are they able to exploit compromising emanations?

Another problem area is the matter of providing guidelines for the design of complete new government buildings in which they expect to use a good deal of equipment for processing classified information. How do we anticipate the TEMPEST problems that may arise and stipulate economical means for reducing them in the design and layout of the building itself? We consult with the architects for new federal office buildings, suggesting grounding systems and cable paths that will minimize TEMPEST suppression cost when they decide to install equipment.

Finally, equipment designers face some specific technical difficulties when certain kinds of circuits have to be used, or when the system must generate or handle pulses at a very high bit rate. These difficulties stem from the fact that these pulses are characterized by very fast “rise-times”.

They peak sharply, and are difficult to suppress. When this is coupled with the fact that on, say, a typical printed circuit board, there just isn't room to get this physical separation between lots of wires and components that ought to be isolated from one another, then mutual shielding or electrical “de-coupling” is very difficult. R&D has published various design guides to help minimize these problems, but they continue to add cost and time to our developments. With crypto-equipment, problems can be particularly acute because, almost by definition, any cryptomachine forms an interface between RED (classified) signals, and BLACK (unclassified) ones, for you deliver plain text to it, and send cipher text out of it—so the notion of RED/BLACK signal separation gets hazy in the crucial machinery where one type of signal is actually converted to the other.

SUMMARY

We have discussed eight separate phenomena and a host of associated problems. We have identified a number of countermeasures now being applied, the main ones being the use of low-level keying, shielding, filtering, grounding, isolation, and physical protective measures. We have traced a program over a period of more than 20 years, with almost all the advances having been made in the last decade, and a coherent national program having emerged only in the past few years. My own estimate of the overall situation is as follows:

1. We should be neither panicked nor complacent about the problem.
2. Such evidence as we have been able to assemble suggests that a few of our installations, but very few of them, are probably under attack right now. Our own experience in recovering actual intelligence from U.S. installations under field conditions suggests that hostile success, if any, is fragmentary, achieved at great cost and—in most environments—with considerable risk.
3. There remain a number of more economical ways for hostile SIGINT to recover intelligence from U.S. communications entities. These include physical recovery of key, subversion, and interception and analysis of large volumes of information transmitted in the clear. But during the next five years or so, as our COMSEC program makes greater and greater inroads on these other weaknesses, and especially as we reduce the amount of useful plain language available to hostile SIGINT, it is logical to assume that that hostile effort will be driven to other means for acquiring

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intelligence as more economical and productive, including increased effort at TEMPEST exploitation. Already, our own SIGINT effort is showing a modest trend in that direction. As knowledge of the phenomenon itself inevitably proliferates, and as techniques for exploitation become more sophisticated because of ever-increasing sensitivity of receivers, heightening fidelity of recording devices, and growing analytical capabilities, the TEMPEST threat may change from a potential one to an actual one. That is, it will become an actual threat *unless* we have been able to achieve most of our current objectives to suppress the equipments we will then have in our inventory and to clean up the installations in which those equipments will be used.

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**A HISTORY
OF
U.S. COMMUNICATIONS SECURITY (U)**

THE DAVID G. BOAK LECTURES

VOLUME II

**NATIONAL SECURITY AGENCY
FORT GEORGE G. MEADE, MARYLAND 20755**

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INTRODUCTION

(U) The first volume of this work was completed in 1966, and except for a brief update in 1972 treating mainly our part in the failure in Vietnam, has remained essentially unchanged. The purpose of the ensuing essays is to provide some historical perspective on some of the trends, concepts, ideas, and problems which have either arisen in the past decade or so or have persisted from earlier times. The material is intended to be essentially non-technical, and is for relative newcomers in our business. Our nuts and bolts are treated in considerable depth in KAG 32B/TSEC. It is commended to readers seeking detail, particularly on how our systems work and the specifics of their application.

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POSTSCRIPT ON SURPRISE

(U) We've encountered no serious argument from anybody with the thesis that COMSEC - a key ingredient of OPSEC - may help achieve surprise, nor with the correlative assertion that fewer and fewer major activities can be planned and executed these days without a large amount of supporting communications to coordinate, command and control them, nor even with the assertion that, without security for those communications, surprise is highly unlikely.

~~(C)~~ But, with all that said and accepted by customers, we may still be faced with the quite legitimate question: "What is its value - How much is it worth?" Is a KY-38 the right choice over rounds of ammunition to an assault platoon? Or all the other trade-offs you can imagine when we cost money, take space, consume power, use people, complicate communications, or reduce their speed, range, reliability, capacity, or flexibility. Can we quantify its value? Rarely, I fear, because we can so seldom show the success or failure of some mission to have been categorically and exclusively a function of the presence or absence of COMSEC. Even in the drone anecdote related in the following OPSEC chapter, where we'd like to credit a few crypto-equipments with the savings of several hundred million dollars worth of assets, there were other contributors like improved drone maneuverability and command and control, and increased EW support to disrupt North Vietnam's acquisition radars.

(U) In a straight military context, however, we know of one major effort to quantify the value of surprise. Professor Barton Whaley of Yale undertook to measure success and failure in battle as a strict function of the degree of surprise achieved by one side or the other. He used Operations Research techniques in an exhaustive analysis of 167 battles fought over a period of many years in different wars. He confined his choice of battles to those in which there were relatively complete unit records available for both sides and chose them to cover a wide variety of conditions which might be construed to affect the outcome of battle - terrain, weather, numerical or technical superiority of one side or the other, offensive or defensive positioning, and so on.

(U) His measures for "success" were the usual ones: kill ratios, casualty ratios, ordnance expenditures, POW's captured, and terrain or other objectives taken. He found that, regardless of the particular measure chosen and the other conditions specified, success was most critically dependent on the degree of surprise achieved. He found:

	<i>No. of cases</i>	<i>Average casualty ratio (friend : enemy)</i>
SURPRISE:	87	1: 14.5
NO SURPRISE:	51	1: 1.7
NO DATA:	29	

(U) The above is contained in Professor Whaley's book (still in manuscript form) *Strategem: Deception and Surprise in War*, 1969, p. 192.

(U) When the extreme cases were removed, the average casualty ratios were still better than 1:5 where surprise was achieved, vs. 1:1 when it was not (*Ibid.* p. 194).

(U) He further asserts that, nuclear weapons and missile delivery systems "...raise the salience of surprise to an issue of survival itself. . ." (*Ibid.*, p. 207).

(U) These seem to be facts worth noting in persuading people that their investment in COMSEC will be a good one; they'll get their money back, and then some. I have to confess, however, that the analogy between Whaley's findings and what COMSEC can do is flawed. For, Dr. Whaley was a World War II deception expert, and he believed that the best way to achieve surprise is through deception rather than through secrecy.

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OPSEC

(U) Since earliest times, one of the basic principles of warfare has been surprise. In fact, some early Chinese writings on the subject are quite eloquent. A strong case can be made that, seen broadly, a major purpose of COMSEC - perhaps its overriding purpose - is to help achieve surprise by denying enemy foreknowledge of our capabilities and intentions. The principle applies not only to strategic and tactical military operations but to the fields of diplomacy, technology, and economic warfare as well. In fact, it extends to almost any adversarial or competitive relationship.

(U) Operations Security (OPSEC) is a discipline designed fundamentally to attain and maintain surprise, particularly in military operations. In fact, I have seen drafts of an Army update of their doctrine on Principles of Warfare in which OPSEC is formally recognized as a supporting factor in the treatment of surprise.

~~(S)~~CCO) The history of OPSEC and our involvement in it flows along the following lines: By 1966, both intelligence sources and after-action reports had made it abundantly clear that the North Vietnamese had sufficient foreknowledge of ARC LIGHT (B-52) and ROLLING THUNDER (tactical aircraft) raids to render many of those operations ineffective. A concerted effort began in an attempt to determine the sources of that foreknowledge. To that end, JCS assembled a group which included DIA, the Services and ourselves. NSA was a player, both because SIGINT had been the source of some of the most convincing evidence of enemy foreknowledge and because communications insecurities were thought to be a prime candidate as the culprit.

~~(E)~~CCO) Early on, the Group decided that an all-source effort should be made. Three basic potential sources for the foreknowledge were soon established - hostile SIGINT exploiting U.S. signals insecurities; HUMINT (Human Intelligence) in which agents could physically observe and report on the planning and execution of missions; and operations analysts deducing the nature of forthcoming activity from an examination of stereotypic (repetitive) patterns revealed by our past activity.

~~(E)~~ OPSEC emerged as a formal discipline when it was decided, I believe at the urging of NSA representatives, that a methodology should be devised which would *systematize* the examination of a given operation from earliest planning through execution: a multi-disciplinary team would be established to work in concert, rather than in isolation; and its membership would include experts in COMSEC, counter-intelligence, and military operations. They would look at the entire security envelope surrounding an operation, find the holes in that envelope, and attempt to plug them.

(U) A most important decision was made to subordinate this OPSEC function to an operations organization, rather than to intelligence, security, plans, or elsewhere. It was thought essential (and it proved out, in the field) that OPSEC not be viewed as a policing or IG (Inspector General) function because, if it was so perceived, operators might resent the intrusion, circle their wagons and not cooperate as the team dug into every step taken in launching an operation. Rather, they were to be an integral part of Operations itself, with one overriding goal - to make operations more effective.

(U) Operations organizations (the J-3 in Joint activities, G-3 or S-3 in Army, N-3 in Navy, and A-3 in Air Force) generally seem to be top dogs in military operations. They are usually the movers and shakers, and alliance with them can often open doors and expedite action. And so it was with the formal OPSEC organization.

~~(S)~~ In a remarkably swift action, the JCS established an OPSEC function to be located at CINCPAC (Commander in Chief, Pacific), shook loose 17 hard-to-get billets, and the OPSEC team known as the Purple Dragons was born. An NSA planner and analyst out of SI was a charter member and was dispatched to the Pacific. The Dragons got added clout by being required to brief the Joint Chiefs of Staff and the President's Foreign Intelligence Advisory Board on their progress each 3 months. They were to support all operations, not just air strikes. They were given a free hand, travelled constantly all over the Pacific, more or less wrote their charter as they went along, and repeatedly pin-pointed the major sources of operations insecurity. Sometimes they were able to help a commander cure a problem on the spot; other problems were more difficult to fix. In the case of air strikes, three of the biggest difficulties stemmed from the need to notify

ICAO (International Civil Aeronautical Organization), other airmen, and US and allied forces of impending operations well before the fact.

(E) Altitude reservations (ALTREV's) were filed with ICAO, and broadcast in the clear throughout the Far East. Notices to Airmen (NOTAM's) specified the coordinates and times of strikes so that they would not fly through those areas, and these notices were posted at U.S. air facilities everywhere. Plain language broadcasts (called Heavy Artillery Warnings) saturated South Vietnam specifying where B52 (ARC LIGHT) strikes were to take place. U.S. officials were obliged to notify and sometimes seek approval of South Vietnamese provincial officials so that they could warn villagers of the coming action.

(E) Some of these problems associated with ARC LIGHT operations were eventually solved by blocking out large air corridors to a single point of entry into SVN airspace; the Heavy Artillery warnings, once transmitted hours before a strike, were withheld until 60 minutes or less before the time on target.

(S) In general, set patterns of operations were rather prevalent in land, sea, and air activity. Ground attacks at dawn were the rule not the exception; hospital ships were pre-positioned off amphibious landing areas; there were runs on the PX before troops moved out of garrison to combat. Major movements of ground forces were preceded by weeks of predictable and observable activity, arranging logistics, setting up convoy routes and bivouacs, coordination with supported and supporting forces and so on. The failure to take COSVN (the North Vietnamese "Central Office for SVN" in the Parrot's Beak area of Cambodia) was almost certainly the result of the huge flurry of indicators of impending attack that preceded it by at least three days.

(E) HUMINT vulnerabilities were pervasive. North Vietnamese and Viet Cong agents had infiltrated most of the country. Yet the Purple Dragons were never able to demonstrate that agent reporting was a dominant factor in enemy anticipation of U.S. action. Rather, communications insecurities emerged as the primary source of foreknowledge in fully two-thirds of the cases investigated. On occasion, a specific link or net was proven to be the source of foreknowledge of a given operation, at least for a time.

(S) A classic case involved the drone reconnaissance aircraft deployed out of South Vietnam to overfly North Vietnam, gather intelligence, and return. By late 1966, the recovery rate on these drones had dropped to about 50%. This deeply concerned us, not only because of the loss of intelligence and of these expensive (\$500K at the time) aircraft, but also because we were certain that North Vietnamese anti-aircraft assets could not possibly have enjoyed such success without fairly accurate foreknowledge on where these planes would arrive, at about what time, and at what altitude. The Purple Dragons deployed to SVN, and followed their usual step-by-step examination of the whole process involved in the preparations made for launch and recovery, and the configuration and flight patterns of the mother ship and the drones themselves, the coordination between launch and recovery assets, including the planning message exchanged. The mother ships staged out of Bien Hoa in the southern part of SVN; the recovery aircraft out of DaNang to the North. Within a few days, the Dragons zeroed in on a voice link between the two facilities. Over this link flowed detailed information, laying out plans several days and sometimes for a week or more in advance on when and where the drones would enter and egress from North Vietnam. The link was "secured" by a weak operations code; the messages were stereotyped, thus offering cryptanalytic opportunities, and their varying lengths and precedences offered opportunities for traffic analysis. In short, the North Vietnamese might be breaking it, or enough of it to get the vital where and when data they needed to pre-position their anti-aircraft assets (surface to air missiles, anti-aircraft batteries, and fighter aircraft) to optimize the chance of shootdown.

(S) As a check, the Dragons manipulated some messages over the link, with fascinating results. (See the March and April 1979 issues of *CRYPTOLOG* for some further details on this account at somewhat higher classification than possible here.) The OpCode was replaced quickly with a pair of fully secure KW-26 equipments. Starting the next day, the loss rate dropped dramatically. A few months later, it began a sudden rise, suggesting that the North Vietnamese had discovered a new source of information. The Purple Dragons revisited, and reassessed the problem. This time they concluded that the unique call signs of the Mother Ships were being exploited. The call signs were changed, and losses fell again, for a few weeks. The final solution was to put NESTOR aboard, and again the loss rate dropped so drastically that, by the end of the drone activity, only one or two drones were lost to enemy action annually in contrast to as many as two or three a week in the early days.

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(c) OPSEC is slowly being institutionalized. OPSEC elements are established in the JCS and at most Unified and Specified Commands. Service organizations are turning increasingly to the discipline but not, as you might expect in peacetime, with great enthusiasm. We have a modest capability for OPSEC in S as well, used largely in support of joint activity or, on request, to assist other organizations. We have also looked inward with the OPSEC methodology in helping DDO maintain the secrecy of his operations, and as still another cut at the general problem of computer security in DDT. Results have been useful.

(e) The principal innovation in OPSEC methodology since early times was the development in SI of a decision analysis routine called VULTURE PROBE to quantify the value of various COMSEC measures by showing how the probability of an enemy's reaching his objectives is reduced as a function of the COMSEC steps we apply. This in turn helps us to decide which information most needs protection, and the relative significance of the many individual security weaknesses an OPSEC survey is likely to uncover.

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ORGANIZATIONAL DYNAMICS

(C) The first Volume described a relatively simple, straightforward functional organization for COMSEC in NSA - the traditional R&D organization for system invention and development, an Engineering organization to manage the production of equipments in quantity, a Materials organization to supply supporting keys and other materials, a Doctrinal organization to approve and regulate use, and a few supporting Staffs. (Please, young people in the line, don't laugh at the sort shrift Staffs usually get in description of who does what. It is more likely than not that it will be to your career advantage to have such an assignment for at least a little while before you are done. I predict that then your perspective on their importance and value will change even though you may now perceive that they are mostly in the way - particularly if you are trying to get something/anything done in a hurry. In general, (but obviously not always) they enjoy the luxury and suffer the uncertainties of having time to think things through.

(C) Our organizational structure changed over time, generally in response to changed requirements, priorities, and needed disciplines. Down in the noise somewhere (except in the scruffy gossip mill) were other factors like personalities, managerial competence, office politics, and so on. The original Doctrine/Engineering/Material triad survived for slightly more than 20 years. Exploding communications technology, quantum jumps in system complexity, speed, capacity, efficiency, reliability, and quantity left our engineers in R and S and our production people strangely unstressed. They had kept pace with technology breakthroughs over the years, and sometimes paced them.

(C) The Doctrinal organization, however, was beginning to burst at the seams. Here was a group that had had little change in numerical strength since its inception, dominated by liberal artists except in cryptanalytic work, trying to cope with technologies so complex in the requirements world that they were hard put to understand, much less satisfy those requirements. A DoD Audit team found, in S, too great a concentration on the production of black boxes and made strong recommendations that we change to a "systems" approach to more fully integrate our cryptosystems into the communications complexes they support.

(C) So, in 1971, came our first major re-organization and S4 (now S8) was born (out of Doctrine by Barlow). Its mission was to get cryptography *applied*. What seemed required was a cadre of professionals, including a liberal infusion of engineers, computer scientists, and mathematicians, in a single organization who would be the prime interface with our customers to define *system* security requirements and to assist in the integration of cryptography to that end. There were, of course, mixed emotions about dilution of our scarce technical talent into a kind of marketing operation, but it paid off.

(C-CCO) By this time, our essential ignorance about hostile SIGINT operations against us was becoming a distinct embarrassment. Despite our insights on some aspects of their activity - e.g., in Washington - our big picture consisted mainly of a panorama of a huge world-wide collection effort, but with little hard data on exactly what they were after or how successful they might be. So we moved from the devotion of a few man-years of sporadic effort on this matter to the creation of an entire Division to delineate the threat.

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§6 of the National Security Act of 1959,
50 U.S.C. 3605 (P.L. 86-36)

(C) A couple of years later (July 1974), another audit report recommended better centralized management and control of cryptographic assets in Government. The Acquisition staff was converted to a full scale line organization (S5) in part in response to that recommendation. There is a persistent view that the ability of an organization to get something done is inversely proportional to the number of people on staff. The

Marine Corps is the arch-type: lean and mean; lots of fighters, little excess baggage in the form of staffers - logisticians, budgeteers, planners, policy makers, clerks, typists, researchers, educators, administrators, and the like.

~~(S-NF)~~ A hoax, of course. The Navy "staffs" for them. No matter what you call it or where you put it, much of that "drudgery" has to be done. The Chief, S5 took some jibes in the form of the assertion that the only reason for the new Office was to improve, on paper, our line-staff ratio. The truth was that, quite apart from the auditor's observations, it was becoming clear that we were moving from an era of a few millions of dollars in procurement annually towards the largest acquisitions in our history (\$202M in FY 1979). Much of that went into the first big VINSON buys. Eventually, by the way, we may buy as many as 170,000 of these equipments - well exceeding our total inventory when Volume I was written. Incidentally, in an extraordinary negotiating coup with the bidders for this work, we documented savings of nearly \$100,000,000 over projected cost. The seven individuals in S5 and S2 most responsible got Presidential citations under a program recognizing major savings in Government. 28% of the total Government savings getting special recognition that year was the work of our people.

~~(S-CCO)~~ By 1976, we were faced with a number of major requirements that crossed many of the existing organizational lines. The big ones were HAMPER (coping with Soviet intercept of commercial carrier communications in the United States); TRI-TAC, into which an unprecedented number of technical personnel resources had been invested by R and S; Mobile Tactical Voice programs such as VINSON, PARKHILL, BANCROFT, and SINGARS, began to burgeon; and Space COMSEC - one of our most highly specialized and demanding disciplines.

~~(S)~~ Now, DDC had five offices, four staffs, and these major projects all demanded managerial time and attention. So, in part to reduce a growing problem of span of control, a new office (S7) was formed in 1977 incorporating all but the HAMPER activity into four Special Project Offices (SPO's), each with Division level status. At the same time, the S1 cryptanalytic organization was split out to form the nucleus of another new Office for COMSEC Evaluations (S6) on a systems-wide basis to include cryptosecurity, TEMPEST, TRANSEC, and physical security.

(U) Ultimately (1978) S4 and S7 were merged into a single Office, S8, which brings us up to date.

THREAT IN ASCENDANCY

(C) In olden times, most of our programs, whether in equipment development, TEMPEST, or security procedures were driven largely by our view of COMSEC weaknesses - our *vulnerabilites* - more or less independent of judgments made on the ability of an opponent to exploit them. We assumed hostile SIGINT to be at least as good as ours, and used that as a baseline on what might happen to us. If we perceived a weakness, we would first try for a technical solution - like new crypto-equipment. If the state of that art did not permit such a solution, or could do so only at horrendous expense, we'd look for procedural solutions and, those failing, would leave the problem alone.

(C) So our priorities were developed more or less in the abstract, in the sense that they related more to what we were able to do technologically or procedurally than to the probabilities that a given weakness would be exploited in a given operating environment. In short, we did not do much differentiation between vulnerabilities which were usually fairly easy to discover, and threats (which were more difficult to prove) - where threats are fairly rigorously defined to mean demonstrated hostile capabilities, intentions, and/or successes against U.S. communications. The accusations of overkill touched on earlier in part stemmed from that approach.

(C) The thrust towards gearing our countermeasures to threat rather than theoretical vulnerability was healthy, and driven by a recognition that our resources were both finite and, for the foreseeable future, inadequate to fix everything. In fact, one of the reactions of an outside analyst to our earlier approach was, "These nuts want to secure the world." Some still think so.

(U) After Vietnam, there was a strong consensus in this country that the U.S. would not again commit forces to potential combat beyond show-the-flag and brush fire operations for a decade or more unless some truly vital interest was at stake - like the invasion of our country. There was a correlative view that such an event would almost certainly not arise in that time frame, and we focussed increasingly on detente and economic warfare.

(C) These views, in turn, suggested that threats would be directed more towards strategic C³ communications than tactical ones and that, accordingly, our priorities should go to the former. So, what did we do? We made the largest investment in tactical COMSEC systems in our history - VINSON. We went all out in support of TRI-TAC, a tactical "mobile" system with more engineers out of R1 and S assigned to it than the totality of effort in the strategic communications arena. Further, the bulk of this effort was in support of securing voice and data only on short *wire lines* (a few kilometers) radiating from the TRI-TAC switches.

(C) How come? I think it was simply a matter of doing what we knew how to do - arrange to secure multiple subscribers on wire in the complex switching arrangement of the TRI-TAC concept. We did not know how to integrate tactical radios within that concept, and so deferred that problem (called Combat Net Radio Interface) while we built our DSVTs, DLEDs, and elaborate electronic protocols to effect end-to-end encryption. We're getting to it now, but the lion's share of the initial effort was devoted to protecting the least vulnerable communications - the ones on short wire lines in the field.

(C) The downgrading of the relative importance (priority) of tactical COMSEC in peace time implied here stems from the fact that an enemy can learn comparatively little from them - he can get OB (order of battle) - the identification, composition, and disposition of tactical forces. He can learn something about new tactics from exercise communications; he can ascertain some things about combat readiness, strength, and proficiency; and, finally, he can gain insights of new weapons systems and other innovations being fielded by U.S. forces.

(U) That sounds like a lot, after all. In peace time, though, most of that kind of information is readily and continuously available through other means - notably HUMINT gathered through routine physical observation, from agent reports, from our own voluminous open publications. . .

(U) I hasten to add that I'd be the last one to push that argument too far. If we denigrate the need for some COMSEC program each time we can point out an alternative way for the information to be obtained,

we can talk ourselves out of business. We do, always, need to be sure that voids in COMSEC do not provide the quickest, most reliable, and risk-free ways to obtain our secrets.

(S) Despite this major aberration—failure to use threat to determine priority—in the general case, the record has been good. As noted, it was certainly the driving force behind the HAMPER program. It accelerated our work in telemetry encryption. It may hasten the modification or abandonment of some marginally secure systems. It certainly precipitated major improvements in some of our systems and procedures for strategic command and control. In its first real application, it changed an unmanagably ambitious TEMPEST program into one that geared suppression criteria to physical environments and information sensitivity in information processors. And it has shaken loose a variety of efforts to improve physical and transmission security.

(U) A caveat: While nothing gets a user's attention like documented proof that communications *he* thinks are sensitive are being read by an opponent, several things should be borne in mind before telling him about it. Foremost is the fragility of the source of the information (the "proof") you have. Secondly, it is worse than useless to go out and impress a user with a problem unless you have a realistic solution in hand. No matter how dramatic the evidence of threat, if we simply go out and say, "Stop using your black telephone," it's likely to be effective for about two weeks. Don't jeopardize a good source for that kind of payoff.

(C) Finally, the results of our own monitoring and analysis of communications, at best, prove vulnerability, not threat, and are often remarkably ineffective. Nothing brought this home more persuasively than the Vietnam experience. Monitoring elements of all four Services demonstrated the vulnerability of tactical voice communications again and again. This did not show that the NVA or VC could do it. It was first argued that they weren't engaged in COMINT at all. Next, that even if they were able to intercept us, they couldn't understand us, especially given our arcane tactical communications jargon. Third, even given interception and comprehension, they could not react in time to use the information.

(C-CCO) It took years to dispel those notions with a series of proofs in the form of captured documents, results of prisoner and defector interrogations, some US COMINT and, finally, the capture of an entire enemy COMINT unit: radios, intercept operators, linguists, political cadre and all. Their captured logs showed transcriptions of thousands of US tactical voice communications with evidence that their operators were able to break our troops' home-made point-of-origin, thrust line, and shackle codes *in real time*. The interrogations confirmed their use of tip-off networks (by wire line or courier) to warn their commanders of what we were about to do - where, when, and with what force.

(U) Lamentably, even with that kind of proof, the situation didn't improve much because our "solution" was NESTOR: users did not like that equipment, and they *had* to communicate, anyhow.

LPI

(U) A traditional way to enhance the security of a transmission is to make it difficult to intercept. The options range from whispering (or the radio equivalent, use of minimum power) to the use of cryptography to spread the transmitted signal unpredictably over a large swatch of the frequency spectrum. In between are armed couriers, physically or electronically protected distribution systems (wire line and, lately, fibre optics), high directivity narrow beam communications (directional antennae and lasers), and hopping randomly and rapidly from one frequency to another.

(C) The impetus for the upsurge of interest in LPI (low probability of intercept) radio transmission systems has come not so much from their potential to secure communications as from the need to prevent jamming. In other words, it's more a question of communications reliability - assuring delivery - than communications security. As noted in Volume I, this fact raises interesting questions on roles and missions for us - anti-jam being traditionally an EW (electronic warfare) matter, not COMSEC, so why were we "intruding" in this arena? The community seems now to accept the idea that we should (we say "must") participate if cryptographic techniques are employed to lower intercept probability. Thus, while we may provide the key generator to spread or hop a signal, we don't get involved in non-cryptographic anti-jam techniques like the design of directional antenna or brute force very high power transmitters to assure message delivery.

(U) While a primary function of LPI is to prevent jamming, a second one of great importance is to provide protection against an opponent's use of DF (direction finding) to locate mobile military platforms when they transmit. If he can't hear a transmission, he has no way of determining where it came from.

(S-NF) Much heavier anti-jam emphasis has arisen because of several developments. First, in the last decade, the focus on Command and Control and the criticality of those communications used to direct forces has intensified, with a recognition that we would be enormously handicapped if those communications were denied to us. The second reason for emphasis stems from growing evidence of Soviet doctrine and supporting capabilities to use EW as a major element of their military tactics and strategy. Finally, some of our forces - notably the Air Force - having begun exercising in "hostile" EW environments, found their capabilities significantly degraded, and thus confirmed a very high vulnerability.

(S) In fact, we were stunned when an Air Force study in the European tactical air environment suggested that their vulnerabilities to jamming were greater than those stemming from plain language air-to-air and air-to-ground voice communications. From this CGTAC reportedly concluded that, since they might not be able to afford both COMSEC and anti-jam systems, they would opt for the latter. One senior Air Force officer reportedly said he needed an anti-jam capability so badly he would trade aircraft for it. With a lot of backing and filling, and more extensive study, we helped persuade the Air Force that they really needed both anti-jam and COMSEC. Army had clearly come to that conclusion as early as 1974 when specifications for their new tactical single channel radio (SINCGARS) called for both a COMSEC module and an anti-jam module. The Army, of course, was also the first to get serious about the business of implementing daily changing call signs and frequencies. I believe their and our motivation in pushing for these procedures was to provide defenses against conventional traffic analytic attacks to determine OB (order of battle). But there is an anti-jam advantage as well - by hiding a unit's identity (callsign change) and his location in the spectrum (frequency change), you force the jammer into broadsides - a mindless barrage, not a surgical strike against the specific outfits that worry him most. That, in turn, exposes the jammer himself to hazard - our location of this interfering signal and, perhaps, launching of homing weapons or something else against him.

(C) One of the more insidious arguments we faced in some circles where anti-jam was asserted to be more important than COMSEC arose from the fact that ordinary cryptography does not add to the resistance of a transmission to jamming. If you can jam the clear signal, you can jam it in the cipher mode. Further, a smart jammer can work against most encrypted signals more efficiently than against plain text, use less power and be on the air for much briefer intervals. This is true, because all the jammer need do is knock the cryptographic transmitters and receivers out of sync or disrupt the initialization sequences that prefix

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most encrypted traffic. This is not the case where we employ CTAK (cipher text auto-key) or where synchronization is dependent on internal clocks rather than timing elements of the cipher text itself. All the others are vulnerable if the jammer can stop them from getting into sync in the first place by repeatedly attacking preambles.

SARK—SOME CAUTIONARY HISTORY

(E) SAVILLE Automatic Remote Keying (SARK), now usually referred to merely as "Remote Keying," is a subject of mild controversy among the elders as to its origins and original goals. One school of thought (memory) insists it was conceived to solve the logistics problem attendant on continual physical distribution and re-distribution of individual hard copy keys to every holder in every net, with the fall-out benefit of reducing security problems by having fewer copies of compromise-prone keys in the pipe-line, in storage, or in operating locations. The other school recalls just the opposite - an initial drive to find a technical solution to the growing problem of key list compromise - particularly through subversion of cleared individuals - and the logistics benefits a matter of serendipity.

(E) Either way, remote keying was the biggest conceptual breakthrough in ways to set up crypto-equipments since the days of the card-reader. But both these potential benefits may be in some jeopardy.

(E) VINSON, the prototype vehicle for remote keying, gets its rekeying variable (its "unique" key) from one of three sources: direct from a key variable generator (the KVG) usually held at net control, or from an electronic transfer device (ETD) which has been previously loaded from a KVG, or from a punched key tape (manufactured by S3) which can be loaded into an ETD with a special tape reader.

(E) For a typical, small, tactical radio net (10-20 holders) the idea was that each subscriber would either go to net control and have his equipment loaded with his variables, or net control would dispatch a courier with an ETD to load his variables *in situ*. Thereafter, he would operate independently of any variables except those electronically stored in his machine until his unique rekeying variable required supersession (usually *one month* unless compromise required sooner change). Meanwhile, he would be rekeyed remotely and independently of any key except that in his machine. No ETD's, no tapes, no couriers, no material to protect except for the keyed machine itself.

(E) Despite repeated demonstrations that the concept would work during OPEVAL (operational evaluation) and in a number of nets in Europe where VINSONs were first implemented, it has not, at least so far, worked out that way.

(E) We have evidently so sensitized users to the crucial importance of their key that they fear leaving it in their equipments when they are not actually in use. We have conditioned them with forty years of doctrine calling for key removal and safe storage when the equipment is not attended or under direct guard. As a natural consequence, it was an easy step to zeroize equipments at night, hold key tapes or loaded ETD's, and rekey themselves in the morning. Result? Easily recovered key at most user locations, now in the form of key tapes and loaded ETD's - a substitution of one kind of readily recoverable key for another, and our physical security is not much improved over what we had with conventionally keyed systems like NESTOR and the KW-7.

(E) Within the next few years, we expect about 140,000 equipments which can be remotely keyed to come into the inventory. At the same time, the users have ordered about 46,000 ETD's and we project the need for 10's of thousands of rolls of key tape to support them, each containing a month's settings. So we're seeing a ratio of 1 to 3 build up, instead of 1 : 10 or less as we had hoped; and our goal of making keys inaccessible to almost everybody in the system may not be realized through remote keying.

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THE CRYPTO-IGNITION KEY

(E) The Crypto-Ignition Key (CIK) is a small device which can be loaded with a 128-bit sequence which is different for each user. When the device is removed from the machine, that sequence is automatically added (mod 2) to the unique key in the machine, thus leaving it stored in encrypted form. When it is reattached, the unique in the machine is decrypted, and it is now ready to operate in the normal way. The analogy with an automobile ignition key is close, thus the name. Should you lose that key, you're still ok unless the finder (or thief) can match it with your machine. You get a new key, effectively changing the lock in your machine, and get back in business.

(S-NF) The ignition key sequence can be provided in several ways. In the first crypto-equipment to use the idea (the KY-70), the CIK is loaded with its sequence here at NSA and supplied to each user like any other item of keying material. Follow-on applications (as in the STU-II) use an even more clever scheme. The CIK device is simply an empty register which can be supplied with its unique sequence from the randomizer function of the parent crypto-equipment itself. Not only that, each time the device is removed and re-inserted, it gets a brand new sequence. The effect of this procedure is to provide high protection against the covert compromise of the CIK wherein a thief acquires the device, copies it, and replaces it unknown to its owner. The next morning (say), when the user inserts the device, it will receive a new sequence and the old copied one will be useless thereafter. If the thief has gotten to his machine during the night, he may be able to get into the net; but when the user attempts to start up in the morning his devices will no longer work, thus flagging the fact that penetration has occurred.

(E) This concept appears particularly attractive in office environments where physical structures and guarding arrangements will not be sufficiently rigorous to assure that crypto-equipments cannot be accessed by unauthorized people.

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PCSM

~~(C)~~ One of our most intractable problems has been to find ways to package crypto-equipment in a way which will seriously deter penetration by a smart, well-equipped opponent with plenty of time. The difficulty is not much different than is faced in the manufacture of three-combination safes. The best we can generally afford can stand up to a covert penetration effort by an expert only for 30 minutes or so, and brute force attacks, leaving evidence, can be done much more quickly than that. Yet, these safes are massive and expensive. With a crypto-box, there are added difficulties in protecting logic or resident key because X-ray devices or electronic probing may recover the information without physical entry.

~~(S-NF)~~ As a result, our tamper-resistance efforts have been frustrated. We either provide no protection at all, and count on external guards, barriers, alarms, and the like; or use "zeroize" features to erase key (but not logic) when a box is opened, or apply nominal security container approaches as in the case of equipments like the KY-3.

25X3, E.O.13526

Withheld from public release under
§6 of the National Security Act of 1959,
50 U.S.C. 3605 (P.L. 86-36)

~~(C)~~ For many years we have known that technologies do exist for building protective cocoons around objects that can in fact provide a very high level of resistance to tampering without triggering some alarm. When we first encountered them, we rejected them out of hand as a practical solution to our problem because these "protective membranes" as they were called, could cost on the order of \$50,000, each.

~~(S-NF)~~ But more than fifteen years have passed since our first encounter with the technique. The process has been refined, and it now appears that we *might* be able to get such packages for under \$500 apiece if we buy in large quantities. This prospect merged in the mind of J. Richard Chiles with the potential for using micro-processors to program various crypto-logics and ancillary functions in a given box. Thus the concept of PCSM - the Programmable COMSEC module - was born.

~~(S-NF)~~ The grand design was (and is) elegant. Encapsulate a micro-computer in a protective membrane. Program it with whatever crypto-logic and assorted keys are required to operate in a given net. Build into each box a unique element of logic or key so that if the membrane is defeated and the contents lost, it will affect no other subscriber's traffic. The membrane serves one function only - to provide, with high confidence, a *penalty* if penetrated. The penalty could range from (theoretically) an explosion to an alarm at some remote place. It might simply zap critical circuitry, disabling the machine, or obliterate all sensitive data (if we learn how to do that).

~~(S-NF)~~ Depending upon the kinds of penalties that prove practical to impose, it may be possible for the entire keyed programmed operational box to be *unclassified*, getting no protection at all beyond that which it provides for itself. Your safe, after all, is not classified. Only its contents. And if all its contents evaporated if somebody (anybody, including you) were to open it, there'd still be no problem. Alternatively, and perhaps more feasibly, it might operate like a bank vault. The money doesn't disappear when somebody breaks in, but other things (alarms) are likely to happen to prevent him from making off with it.

~~(S-NF)~~ A final element in the concept is the use of some central office, switch, net-controller, NSA (!) or some such to electronically check the presence and health of each box. Thus, equipments in storage or in operational locations could not be removed, physically intact without detection, and internal malfunctions in the protective system could be determined without local effort.

~~(C)~~ The goal is not a "perfectly" secure system - rather one good enough to make the risk of detection to an opponent unacceptably high.

~~SECRET NOFORN~~

(~~S~~-NF) Maybe by the time somebody writes Volume III of this work, PCSM can be discussed in the present tense. I hope so, because it constitutes the biggest conceptual step forward since remote keying. Most of this material is classified SECRET to help us achieve technological surprise, and it should *not* be discussed outside NSA without prior approval from DDC.

NET SIZE

~~(C)~~ The cryptosecurity implications of very high volumes of traffic using the same key have not been a dominant factor in determining net size in most of our cryptomachines for many years. Rather, we have opposed very large networks sharing the same key in recognition of the fact that the likelihood of physical compromise rises with the number of copies of materials we make and the number of people to whom it is exposed. Correlatively, the longer a given item is in existence the more opportunities for its compromise arise, and supersession rates are based, in part, on that fact. (A physical security Vulnerability Model has been devised which permits some trade-offs between these two facts - larger nets with more rapid supersession rates, and vice versa.)

~~(C)~~ In olden times, there were limitations on the basic sizes of many communications nets themselves and this put natural limits on shared keying materials when these nets were secured. Now, world-wide compatible communications capabilities are much more prevalent, and operational demands call for more very widely held keys for use in these networks. Eventually, however, there is a sticking point where the risk of compromise becomes prohibitive.

~~(S-NF)~~ Although we've never had any hard statistical probability in our hip pockets, we have generally felt comfortable with net sizes on the order of 250-400 holders, but have tolerated a few nets with upwards of 2000 holders, one KW-7 system with 4900 keys, and the horrendous KI-1A net of 5,945 copies. The rationales for accepting some of the larger nets are sometimes tortured. Instead of looking only at some rough probability of compromise as a function of exposure, we look also at the environment of use - systems in confined enclaves on shipboard seem less vulnerable to compromise than in large plants with many people milling about, or in small field locations where secure structures may not be available. Some systems can be subjected to special protective measures - notably two-man controlled materials - that may offset the existence of large copy counts.

~~(C)~~ The sensitivity or importance of the traffic in given networks may vary greatly, thus affecting the motivations for hostile elements to risk acquiring key, and the long-term security impact should compromise in fact occur. Finally, of course, traffic perishability affects our judgments. In the classic case of KI-1A, we could not care less about the compromise of the key to the world at large one minute after the key is superseded. (This system for identification of friend or foe is useful to any enemy only if he can acquire it before or while it is being used so that he can equip his forces with a means to be taken for a friend.)

~~(S-NF)~~ Still and all, the subjectivity inherent in this approach - as in most physical security judgments - drives us nuts. We are being asked to "quantify" the unquantifiable - the integrity of our people; the physical security conditions at more than 3000 separate cryptographic accounts and the tens or hundreds of individual locations they each may serve; the "value" of tens of millions of messages; the opportunities for subversion, catastrophe, carelessness to result in the compromise of some number of the millions of items we issue annually - and so on. The real force behind the persistent efforts to find technological, measurable solutions to the problems of physical security stems in part from that frustration. There is a justifiable disillusion with our "doctrinal" and "procedural" remedies because enforcement is difficult, they are easy to circumvent deliberately or accidentally by friends and enemies alike, and there is no real way to determine their effectiveness. We *need* the technical solutions - secure packaging, remote keying, PCSM, emergency destruction capabilities, and so on.

~~(S)~~ Meanwhile, let us not rationalize ourselves into some fool's paradise because we have such good and stringent rules and some soothing perceptions that the Soviets, say, aren't really all that proficient. Some of what we still hear today in our own circles when rigorous technical standards are whittled down in the interest of money and time are frighteningly reminiscent of the arrogant Third Reich with their Enigma cryptomachine.

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EQUIPMENT CLASSIFICATION

(C) One of the more difficult doctrinal issues in our business relates to the level of protection we require for crypto-equipments. As briefly noted in the first Volume, the problem has been around for a long time. By 1970, the pressures for easing our protective criteria had become very strong. Users sought relaxed standards not only on the matter of equipment classification, but also for the whole range of rules regarding clearances, storage, guarding, accounting, access authorization, high risk deployment, key supersession rate, net size, foreign access, and compromise reporting.

(C) A special working group was set up consisting of some of our people and representatives of the Services and a few Civil Agencies to review the matter. They found not less than 55 different sets of regulations governing various aspects of the protection of cryptomaterial including basic NSA documents and a myriad of user implementers and amplifiers of those rules. Some contradiction was inevitable. They proposed the elimination of a number of control requirements and drafted a sweeping new, simplified National Level document (NACSI 4005) which emphasized keying material protection, eased the requirements for equipment protection, and allowed classification alone to govern the protection of all other cryptomaterials (maintenance manuals, operating instructions, and so on).

(U) Central to this new departure was the concept of unclassified "Controlled COMSEC Items" (CCI), and the vision that some crypto-equipment, notably tactical equipment, could be, at NSA's discretion, unclassified (but Controlled) when unkeyed.

(C) For the record, the background on the whole question is somewhat as follows: Since the mid-50's, various customers had been calling for unclassified equipments, particularly in the tactical arena, and had been resisted by us for reasons of COMSEC, SIGINT, and technology transfer. Throughout the '60's, pressure built as more and more systems proliferated to lower echelons, and culminated with the feed-back from Vietnam about non-use of NESTOR.

(C) The two major reasons for declassification were the "inhibition of use" argument, and the vision of full integration of COMSEC circuitry into radios of the future - full integration being defined as inseparable and shared radio and crypto-circuitry. In that configuration, our COMSEC tail would be wagging the communications system dog with the controls classification denotes - how would such equipments be shipped, stored, and particularly, how would they be maintained? "Integration" has thus far not turned out to be the wave of the future. COMSEC modules will by and large be separable from their associated radios because the designers found it more efficient to do it that way. At this writing, only BANCROFT fully embodies the original fully integrated concept. Difficulties in protection will persist even with partial "integration," of course. At the moment, though, they don't look to be nearly as severe as we first perceived.

(S) When we got to the heart of the question of non-use of equipments in the field, we found that classification *per se* had little to do with it. (See NESTOR in Vietnam). Besides, our new protective doctrine of 1973 (NACSI 4005) had stripped away many other security-motivated irritants. We deleted the CRYPTO caveat from everything except key; and even with key, it simply denoted material that had to be shipped and controlled in crypto-channels. It no longer implied any special clearance - just need to know, and specific CRYPTO-authorization for access was no longer required. We dropped serial accounting as a nationally imposed requirement for crypto-equipment. It was later re-instated by agreement among ourselves and our prime customers because it was found that configuration control was difficult or impossible without it. Finally, we formalized something that had already been implicit, that the level of protection actually afforded the equipment in the field rested on the judgment of the commander. Surprisingly, that "concession" was not universally welcomed. Some Commanders argued that they wanted explicit rules (which, of course, we could not provide because there is no way for us to anticipate every circumstance in the field, particularly in fluid combat situations).

(S-NF) There were seven subsidiary arguments against classification and counter-arguments for each:

- The design assumption of equipment (or logic) loss, countered by facts that such loss is not certain, not necessarily early after design or deployment, and not universal - loss to one or two countries does not equate to loss to all (on the order of 160) others.

- The impact on SIGINT may be illusory. Unsophisticated countries cannot duplicate, operate, or maintain such high technology - sophisticated countries would not use systems based on US logic or technological base. It was noted that we have never seen a single use of US cryptologic by any foreign country despite a number of losses. Some of those losses, as in the case of SVN, were in significant quantity. Counter-arguments asserted that, while the systems might not be used *in toto*, some of the techniques could be adopted or adapted by SIGINT target countries - approaches to alarming, TEMPEST suppression, and circuitry blocking special cryptanalytic attacks, for instance.

- The CONFIDENTIAL clearance offers a low confidence in the integrity of an individual because the investigation is superficial, so what are we really buying in the way of protection? The counter: we are buying a powerful legal sanction against deliberate compromise of the system to an enemy. Lack of classification has been construed as a "near absolute defense" against prosecution - espionage laws, in practice, apply only to classified (and Formerly Restricted Data) information.

- Executive Orders setting up the classification system are awkward when applied literally to hardware - the classification system was clearly designed with two-dimensional objects (paper) principally in mind. Counter: we've nonetheless lived with it rather well. Further, the Executive Order really leaves no option: if loss of the material is judged damaging, it must be classified.

- Dollars for manpower and facilities required to protect classified hardware could be saved. Counter: Savings would not be significant given the requirement for a reasonable alternate set of controls on the equipment - particularly since *classified* keys are used in association with the equipment in operational environments.

- The design of modern equipments can provide inherent protection against logic recovery. Counters: "Secure" or tamper-resistant packaging have not panned out yet. (But see article on PCSM potential.) Similarly, early efforts for extraction resistance and automatic zeroizing have proved disappointing. Early hopes that the complexities and minuteness of micro-electronic components would make their "reverse engineering" difficult have been proven unwarranted.

- Alternative controls to classification could be devised which would provide equivalent or better protection. Counter: when we actually fielded early models of VINSON and PARKHILL as unclassified but Controlled COMSEC Items (CCI) for Service tests, the system broke down. Within a few months, we had an astonishing number of gross violations - lost chips and whole equipments; display of equipment at an open convention with a Soviet presence; demonstrations of equipments - including remote keying procedures - to boy scouts and wives' clubs, and extremely casual handling. We simply could not articulate the requirements to protect these equipments despite the lack of classification. The nearly universal reaction when we fussed was "If their loss is really damaging to U.S. interests, why aren't they classified?" Without exception, in our contacts with Congressional people, we got that same reaction when they were interceding for constituents demanding a share in the market for Design Controlled (but unclassified) Repair Parts (DCRP's). We learned, the hard way, that classification does significantly lower the probability of compromise.

(S) Probably among our less judicious moves in seeking alternative controls for tactical crypto-equipment was the notion of treating them "like a rifle" without first researching what that really meant. On the one hand, it did mean a high level of protection *in the field* because rifles were items for which individuals were personally and continually accountable. Most of these same individuals perceived that their lives might well depend on them. But crypto-equipments - at least until secure squad radios come along - are not items of personal issue, and we have by no means yet convinced most users that their lives may depend on these devices even though we think we can prove that is sometimes true.

(S) We also found, of course, that controls over small arms in the Services aren't all that great when they aren't in the hands of individual users. The system for distribution and warehousing is evidently quite weak because DoD acknowledges that many thousands of them cannot be found, or are showing up in large quantities in the hands of various other countries, terrorist groups, the criminal element, and the like.

Losses of that magnitude in our crypto-equipment inventory would be disastrous, principally because it would put some elements of DDO out of business.

(C) So we backed away from treating them like rifles, and toyed with the idea of treating them like radios. We had heard that such "high value" items got good control, and that protection in the field would be roughly equivalent to that expected for crypto-equipment. The argument was that classification was unnecessary because it offered no real security advantage. We approached this proposition cautiously, partly remembering the large number of tactical US radios that eventually formed the backbone of the North Vietnamese and Viet Cong radio nets, and decided to do an empirical test on the relative protection afforded to radios and crypto-boxes in the same field environment.

(C) We enlisted the aid of Army and Air Force counter-intelligence personnel under a project called JAB. During a major exercise (REFORGER '74) in Europe where NESTOR and KI-1A equipment was deployed, we dispatched small counter-intelligence Tiger Teams to see how many crypto-equipments and how many radios they could "acquire" in the same environment. By "acquire" we meant 30 or more minutes of unrestricted access - long enough to steal equipment, extract keys, or recover the internal wiring. The results were interesting.

(S-NF) In a few weeks, the team deployed against NESTOR-equipped Army units "acquired" dozens of radios, sometimes together with their parent jeeps and other vehicles. But when they tried to get the CONFIDENTIAL NESTOR's, they met suspicion, distrust, and were nearly caught repeatedly. They managed substantial access to only one NESTOR equipment during the entire operation. That equipment was mounted on a jeep in a guarded motor pool. It was night time, and there was a driving snow-storm. The guard was described as concentrating strictly on the business of keeping alive.

(S-NF) The team seeking KI-1A in various aircraft had quite a different experience. Like their Army counterparts, they had forged identities and orders, and a few fake messages announcing their "visits" to a number of airbases. These devils posed as technicians from NSA checking possible TEMPEST anomalies using their "specially equipped" van. They conned various base personnel into allowing them, unescorted, on board various aircraft or to turn equipments over to them for "testing" in their van. In one case they were given fully keyed equipment.

(C-NF) Inevitably, after success at three consecutive airbases, some crusty old custodian got suspicious and started checking back on their bona fides. The word went out to AF units all over Europe and they barely escaped arrest at their next target. As you might expect, when they debriefed senior AF officials in Europe, the commanders were considerably more exercised over the fact that the team could have flown off with whole airplanes than with the security of the KI-1A.

(C) So, in the Army case, we found a substantial difference in protective levels for radios and crypto-equipments; but in the case where radios and crypto-equipments usually were collocated - i.e., on aircraft - there was no real difference.

(S-NF) Despite this demonstration, performed only to prove a specific point, hostile agent operations of the kind simulated in JAB have never been our primary concern. We think such operations are rare. Among our many thousand cases of possible compromise over the past 30 years, we have not one proven incident of hostile penetration of a vault, cryptocenter, motor pool, or guarded flight line to acquire crypto-material. We don't deny the vulnerability but are dubious about the real threat, because the risk may be perceived to be too high to the penetrator.

(S) A much safer way for a hostile government to get at these materials is through subversion of cleared people with routine access to them. This has been done a number of times that we know of, sometimes with very serious consequences. With this technique, some American, not a foreign spy, takes all the risks of getting caught. Until he does, he can offer materials repeatedly as in the most recently publicized case of John Boyce - the employee in a cryptocenter at TRW who was reportedly involved in at least a dozen separate transactions involving sale of keying material and photographs of the logic circuits in one of our crypto-equipments. (The case is well-documented in *The Falcon and the Snowman*. Simon Schuster, 1979.)

(S-NF) Coping with this kind of problem is, in part, what remote keying, ignition keys, tamper-resistant packaging and, on the horizon, PCSM are about.

(C) The narrative above addresses principally the matter of classification as it relates to crypto-equipment. There follows a more generic treatment of what underlies our efforts to protect cryptographic information in

general, and offers a perspective on the kinds of information a SIGINT organization finds useful in doing its job.

(S) NSA spends tens of millions of dollars and tens of thousands of man-hours trying to discover what Soviet COMSEC is like. Despite all-source research dating back more than 30 years, the incidence of *any* unclassified statements by the Soviets on any aspect of their COMSEC program is so trivial as to be virtually non-existent. In other words, the Soviets protect (classify) all information about their cryptography and associated communications security measures.

(E) The effect of this stone wall has been either to greatly delay U.S. ability to exploit some Soviet communications or to frustrate it altogether.

(E) Viewed as an element of economic warfare, we are losing hands down as we expend enormous resources to acquire the same kind of information from the Soviets that we give them free - i.e., without classification.

(E) Clearly, the Soviet's classification program costs them something, just as ours costs us. But, they have a cost advantage because they still operate in an essentially closed society with a well-established security infrastructure and with many of their officials already well attuned psychologically to the concept of secrecy.

(E) Where we do classify, our tangible costs can be measured in lessened program efficiency and timeliness, and in the cost of the security barriers we then need to build around the information or material. The major intangible penalty is still asserted to be the "net loss" to COMSEC when classification inhibits system use.

(S) The optimum attack on any cryptosystem (if you can hack it) is cryptanalytic - you need only operate on cipher text; your risk is low or non-existent unless you have to position yourself dangerously to perform the interception. You don't need to steal keys or penetrate cryptocenters or subvert people and, if you succeed, the return on investment is likely to be rich - all the secrets committed to the cryptosystem in question. The one essential pre-requisite to such attack is knowledge of the cryptologic - which may have been the reason why the Soviets were (reportedly) willing to offer \$50,000 for PARKHILL several years ago.

(S) Accordingly, a first line of defense has to be to protect our cryptologies (and our own diagnoses thereof) for as long as we can, regardless of our sense of the inevitability of eventual compromise. In fact, it turns out that we have *evidence* of the loss to an enemy of only about half of the types of crypto-equipment (or their logic) now in use; many of those known losses occurred only after the systems had been in widespread use for many years; and the lost material in all likelihood reached only one or a few of the dozens of potential adversaries who might be able to use it for their own SIGINT or COMSEC purposes. In part because of this multiplicity of adversaries, all of whom might benefit from knowledge of our equipment, we do *not* declassify them even when we know they have been lost.

(S-CCO) The "SIGINT" argument for protecting our cryptologies is well known - the COMSEC arguments much less so, despite their reiteration for some decades:

- With the exception of true one-time systems, none of our logics is theoretically and provably immune to cryptanalysis - the "approved" ones have simply been shown to adequately resist whatever kinds of crypto-mathematical attacks we, with our finite resources and brains, have been able to think up. We are by no means certain that the Soviet equivalent of A Group can do no better. But no attack is likely to be successful - and certainly cannot be optimized - without preliminary diagnostics - discovery of how it works.

- Systems which have no known cryptanalytic vulnerabilities may still be exploited if, and usually only if, their keying materials have been acquired by the opposition or if their TEMPEST characteristics permit it. In either of these contingencies, however, the logic, the machine itself, or both may be required for exploitation to be successful.

(E) Because the thrust for unclassified when unkeyed equipments is lying fallow at the moment, all of the above may seem like beating a dead horse as far as our mainline equipments are concerned. But the matter will assuredly rise again.

(E) In any event, most people in S are pretty well sensitized and/or resigned to the need for protecting logics and precise information about their strengths and weaknesses. However, that is not the case with

large batches of peripheral information about how we obtain communications system security. We tend to play fast and loose with information about alarm structures, about "TRANSEC" features, depth protection, anti-jam protection, cryptoperiods, keying techniques, testing, financial and logistics arrangements, parts catalogs, plans, schedules, operating instructions, physical safeguards, and usage doctrine in general.

(U) Attempting to protect some of this data is sometimes viewed as hopeless or useless, either because it becomes self-evident the instant a given system hits the street or because it has leaked into the public domain over the years or decades.

(E) But beware arguments for declassification on grounds that the information - in bits and pieces - has already been published in unclassified form. Hostile intelligence is not ubiquitous, and we ought not to be compiling "unclassified" data for him, especially when blessed by our rather exceptional stamp of authenticity. And it would be well to remember that our classification of materials on the basis of their aggregate intelligence value still carries weight, despite the discomfiture when people ask which paragraph, which sentence, which word?

(U) But decisions to declassify anything about a new (or old) system should be made case by case, and at least as much thought should go into the whys of declassification as to the whys of classification. I don't think the burden of proof should lie with either the "classifier" or the "declassifier."

(U) In the final analysis, the "classifier" has only two arguments going for him - enhanced security and/or enhanced US SIGINT operations. The "declassifier" likewise has few bottom lines - enhanced COMSEC operations and - often - cost savings. The trouble is, there's usually *some* merit on both sides and, as apples and pears are involved, the "decision" is usually subjective and contentious.

(E) The further trouble is the tendency of both "sides" to throw up smokescreens in the form of specious argument or unsupportable assertions - emotionalizing the whole process:

(E) COMSEC and SIGINT "classifiers" are quite capable of asserting irreparable harm where little or none exists in the real world - past insistence on patent secrecy for trivial devices being a case in point.

(E) Likewise, in the case of the declassifiers - e.g., a tactical voice security advocate claiming the VINSON and PARKHILL programs would collapse if we insisted on their classification.

(E-CCO) Perhaps, however, the biggest single shortcoming among people in S deciding on (de)classification of information stems from far too hazy a perception of how the SIGINT world - any SIGINT world - operates, and the practical difficulty that world encounters in acquiring all the data they need to target and exploit a given communication system. The process is expensive and complex, and entails well-defined steps of collection, forwarding, processing, analysis, and reporting.

(E) Before committing assets to an attack, they need to know not just the cryptosystem, but the associated communications, the nature of the underlying traffic, deployment plans - where, when, who, how many. So the data that is valuable to them includes:

- The size of the program
 - How much are we spending on it
 - How many copies will we build
- Who the users are
- Where they will be located
- Communications platforms and frequencies
- Deployment schedules, TechEvals, OpEvals, IOC's etc.

(S) Given all that, and the cryptologic, they can begin to get down to the serious work of deploying collection assets, adjusting targetting priorities, massing the people and equipment at home or in the field to carry out attack. That may take years. Thus, in short, the more advance knowledge of future crypto-system deployments they have, the better they can plan and schedule their attack. Were we ever to field a major cryptosystem with complete surprise (we never have), we might well be home free for some years even if that system had some fatal flaw of which we were unaware.

(E-CCO) So, one root question we need to ask ourselves when we are trying to decide whether something need be classified or not is: "What would be the value of the information if I were part of a hostile SIGINT organization - any such organization?" "Will its protection block or delay potential efforts against us?" A correlative question - equally difficult for COMSEC people to answer - is: "will it be useful to an actual or potential US SIGINT target by showing that target something it can use to improve its own COMSEC

equipment or procedures?" "What would our own SIGINT people give for comparable information about targetted foreign cryptography?" A trap to avoid in attempting that answer is conjuring up only the Soviet Union as the "target" in question. Clearly, there are categories of information which would be of little use to them because of the level of sophistication they have already achieved in their own cryptography, but could be of extreme value to other countries.

~~(S)~~ On the top of all of the above, our perceptions of threat had been sharpened by evidence of an intense Soviet effort to acquire cryptoequipment, subvert people with access, and willingness to attack high-grade U.S. cryptosystems.

25X3, E.O.13526

~~(e)~~ All this activity culminated in our abandonment, at least for now, of the commitment to make most tactical equipment unclassified. Our announcement to that effect caused some grumbling among our customers, but not the brouhaha we had anticipated.

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§6 of the National Security Act of 1959,
50 U.S.C. 3605 (P.L. 86-36)

PUBLIC CRYPTOGRAPHY—SOME CAUSES & CONSEQUENCES

(U) This strange term remains imperfectly defined at this writing. It seems to relate to all of the following:

- Commercially designed cryptosystems available to the general public.
- Government-designed (or endorsed) cryptosystems made similarly available.
- Cryptographic schemes and cryptanalytic treatises published in open literature by academicians and others interested in the subject.

~~(S)~~ While commercial equipment has been around for many decades, their quantity and variety was relatively small. Most were manufactured overseas - particularly in Switzerland, and no huge market existed for them after World War II because many Governments (like our own) began increasingly to use systems exclusively of their own design and under their own control. Similarly, the amount of published literature on cryptography, and particularly on sophisticated cryptanalytic ideas was sparse. In the U.S., the Government (specifically, NSA) enjoyed a near-monopoly on the subject by the early '50's. That persisted until about 1970, when a dramatic change occurred.

~~(S)~~ A handful of U.S. companies interested in computers, in communications, or in electronics began to perceive a market for electronic crypto-equipments. A few other American companies began building crypto-equipment in competition with the Swiss and others in Europe, supplying devices to some Governments in Africa, South America, and the Middle East and to a few major corporations - notably some oil companies seeking to protect vital industrial secrets.

(U) At about the same time, the question of computer security, which had been on the back burner since the late 50's, began to get a great deal of attention from computer manufacturers themselves and from some of their customers. Computer fraud had become more common, and its impact, particularly on the banking world, became significant.

(U) In 1974, the Privacy Act (P.L. 93-539) was passed, imposing a legal obligation on Government Departments and Agencies to protect the information held on private citizens - notably in computer banks. Since data was increasingly being communicated among computers, the need for some means to secure these transmissions became evident. Thus, the perception of a need for encryption arose in the public sector.

(U) The Department of Commerce has an element charged with improving the utilization and management of computers and ADP systems in the Government. They, especially, perceived a requirement for commercial sources for cryptography to protect Government computer communications and, correlatively, the need for an Encryption Standard applicable to any system offered to Government against which commercial vendors could design security devices. This Standard, the Data Encryption Standard (DES), was published by the National Bureau of Standards as Federal Information Processing Standard No. 46 in January, 1977.

(U) The process involved solicitation for proposals for such a "standard" encryption process or algorithm and two public symposia were held by NBS to discuss the merits of the winning submission (IBM's). A small storm of controversy erupted when some academicians said it wasn't good enough, and implied it had been deliberately weakened so that the Government could break it. Heretofore, in the COMSEC business, publicity of any kind - much less adverse publicity - was rare, and we were not happy. However, a Congressional investigation exonerated NSA and the issue subsided somewhat.

~~(S-CCO)~~ Another major factor arose bringing great pressure on NSA to let some of our cats out of the bag. This was the matter of Soviet interception of communications in the Washington area and elsewhere in the United States. By 1966, we were pretty sure that they were doing this work from their Embassy on 16th Street and perhaps from other facilities as well - but we had no clear idea of its scope, its targets, possible successes, nor of the value of the information they might be collecting.

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dedicated lines flowing through the commercial links - which appeared to be most critical to defense operations, and quietly arranged for them to be switched from microwave to cable. They were, in the main, communication circuits supporting Strategic Command and Control. We knew that, by so doing, we would greatly complicate the Soviet intercept problem, and make it impossible for them to carry it out risk free.

(S-CCO) By the early 70's, evidence had accrued confirming the Soviet intercept effort, and it was shown to be large and efficient. [redacted]

[redacted] characterized their intercept effort from their Washington Embassy as the single most valuable covert SIGINT activity in their arsenal. The vulnerable communications obviously extended beyond those of our traditional military and diplomatic customers. Privacy for individual citizens could be violated; technological information communicated by Defense contractors could be compromised, and information useful in economic warfare could be obtained. The threat became public and explicit in the waning days of the Ford Administration with Vice-President Rockefeller announcing in a press conference that "If you don't want it known, don't use the phone." Later on, in a press conference, President Carter acknowledged the existence of the problems, characterized the Soviets' effort as passive, noted that all "his" communications were secured, and did not appear too upset. Senator Moynihan, however, expressed outrage, wanted to jam the Russians, expel them, or something because of their outrageous invasion of U.S. citizens' privacy.

(C) By this time, we had bitten the bullet, deciding to seek a generic COMSEC solution. This was a decision of enormous consequence for us. The notion of injecting Communications Security into the commercial world in a big way was unprecedented, with serious policy, political, and technical implications for all involved. Principal players became ourselves, the telephone companies, the White House, DCA, the now defunct Office of Telecommunications Policy in OMB, FCC and, ultimately many users of the commercial telephone system.

(S-CCO) The project was (and is) called HAMPER. At the outset, it had three main thrusts: a greatly expanded program to move "sensitive" circuits to cable in Washington, NYC, and San Francisco where major Soviet Intercept activities were now known to exist; a program to bulk encrypt some of the tower-to-tower microwave links in their entirety, re-inforced by end-to-end encryption for some particularly critical lines; and the definition of "Protected Communications Zones" (PCZ) to circumscribe those areas - e.g., Washington and its environs - from which microwave interception would be relatively safe and easy. It took several years of concerted effort simply to sort out how communications were routed through the enormously complex telephone system.

(C) The doctrinal problems were large and intractable because they involved the provision of cryptography in unclassified environments where many of our traditional physical security measures were thought to be inapplicable. How would the crypto-equipments be protected? How to protect the keys? How do you effect key distribution with no secure delivery infrastructure such as we enjoy in the Government COMSEC world? Problems of this kind led to a campaign to use the DES - the only unclassified Government-approved cryptosystem available, thus solving the physical security problem insofar as the crypto-equipment itself was concerned. The root difficulty with this proposal from the security analysts' viewpoint lay in the fact that the DES algorithm was originally designed and endorsed exclusively for the protection of unclassified data, fundamentally to insure privacy, and without a SIGINT adversary with the power of the Soviet Union having been postulated as a likely attacker. Accordingly, the system was not designed to meet our high grade standards and we were not interested in educating the world at large in the best we can do.

(S) Nonetheless, the system is very strong; has stood up to our continuing analysis, and we still see no solution to it short of a brute force exhaustion of all its 2^{56} variables. It is good enough, in fact, to have caused our Director to endorse it not only for its original computer privacy purposes, but for selected classified traffic as well. Cynics, however, still ask "Are we breaking it?" The answer is no. But could we? The answer is "I don't know; if I did I wouldn't tell you." And there's a good reason for this diffidence. A "No" answer sets an upper limit on our analytic power. A "Yes" answer, a lower limit. Both of those limits are important secrets because of the insights the information would provide to opponents on the security of their own systems.

(C) The event with the most far-reaching consequences which stemmed in part from our having grabbed this tiger by the tail was the re-organization of the COMSEC effort at the National level. Historically, NSA had been the *de facto* and *de jure* National Authority for all Government cryptographic matters - a position

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established by sundry Executive Orders, Directives, "charter" documents and the like reaching back to 1953. But, by mid-1976, attacks on us by a small but vocal contingent of Academe had become bitter. Some elements of the National Science Foundation which underwrote much of the cryptographic work done in the private sector joined in the beginnings of the adversarial relationship vis a vis NSA.

(E) A fundamental challenge related to the *propriety* of an "intelligence" organization having jurisdiction over the privacy of citizens in the post-Watergate climate. In short, could we be trusted? An early action of the Carter Administration, therefore, was to issue a Policy Review Memorandum (PRM 21), to examine this issue and recommend a course of action. The result - 11 months later (Nov '77) - was a Presidential Directive (PD 24) effecting a basic realignment of roles and missions in Government for COMSEC and for something different called "Telecommunications Protection."

(E) The Secretary of Defense remained the Executive Agent for Communications Security, but with COMSEC now defined to relate only to the protection of classified information and *other information related to national security*. A new Executive Agent, the Secretary of Commerce, became responsible for "Telecommunications Protection," defined to encompass information *not related to national security*. In both cases, the threat was defined to be exclusively "foreign adversaries" and nobody was charged with "domestic" threat - e.g., those engaged in computer fraud, industrial espionage, drug smugglers, terrorists, and the like who may be exploiting communications.

(E) So, the split-out of roles and missions did not relate in any direct way to the kind of cryptography or other protective measures that may be used, nor to the specific customers to be served by one Executive Agent or the other, nor to the specific communications means in question nor, finally, to the nature of the opposition. It relates only to the underlying nature of the information to be secured (protected). For the past two years or more, we and the Department of Commerce have been trying to sort it out. Not the least of the difficulties is that many communications systems carry a mix of security-related and non-security related information - notably, of course, those of the telephone companies. So who's in charge?

(E) While these events gathered steam, the HAMPER program faltered because of uncertainties on who was charged with, responsible for, authorized to, or capable of moving forward. Big money was involved, and we didn't know who should budget for it. Should the common carriers pay for it themselves, or its customers? Or the government? It is, after all, a security service that most may not want or perceive a need for.

(E) A handful of people from the now defunct Office of Telecommunications Policy (OTP) were transferred to a new organization within the Department of Commerce (DoC) to form the nucleus of an Agency charged to implement their part of PD-24. The new Agency is called the National Telecommunications and Information Agency (NTIA) and they are the people with whom we deal daily in trying to carry out our obviously overlapping missions. A few of our former colleagues joined that Agency to help them acquire the technical competence to deal with cryptographic questions, system selection, application, and the like. We are travelling a rocky road in these mutual endeavors because, quite apart from the potential for jurisdictional dispute, we have philosophically different orientations. By and large, most people in both the COMSEC and SIGINT organizations in NSA believe that we can accomplish our missions more effectively in considerable secrecy because it helps us to conceal our strengths and weaknesses and to achieve technological surprise. DoC, on the other hand, is in business, in part, to encourage private enterprise, to maximize commercial markets at home and abroad, and to exploit the products of our own Industry for use in Government rather than having the Government compete with Industry - and this does not exclude cryptography.

(E) While, in DoD, Technology Transfer is viewed largely as a security issue with concerns oriented towards export control for critical technologies, Commerce is interested in the infusion of our own industry with technologies now controlled by the government. They need, therefore, to maximize the declassification of information relating to cryptography. Their in-house resources remain meager, so they are turning to commercial research organizations to develop cryptographic expertise. Since these contracts are usually unclassified, and we fear the consequences of publications of what the best private sector brains may have to offer, there is some continuing tension between us.

(E) Through all this controversy, and notwithstanding our security concerns (some will read "paranoia"), there is a very strong motivation among us for cooperation with DoC, with Industry, and with the Academic

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community to get the Government's business done. Clearly, because of that near-monopoly I spoke of, we have a head start in NSA on cryptographic matters. Just as clearly, we have no monopoly on brains nor on manufacturing innovation and ingenuity. Potential security losses may well be off-set by what a motivated commercial world and interested Academe might offer to the Government for its own use. There is a school of thought that believes that various commercial offerings - notably those which may embody the DES - may fill a gap in our cryptographic inventory which our own systems cannot fill because of their design against high and costly standards and tough military specifications, their protection requirements, and the protracted periods of time they generally take to produce. Note, for example, that after all these years, a significant majority of military voice communications and almost all non-military Governmental voice communications remain unsecured. Inexpensive and quickly available commercial voice equipments might move into this vacuum and - even though they may generally offer less security - we might enjoy a net gain because otherwise, for many years to come, those communications will be there for the taking, essentially free of cost to an opponent. This argument does not mollify the conservative, however.

(U) At this writing, some uncertainty remains as to how large the market for commercial devices, notably DES, may be. There seems to be a consensus that they may be applied in considerable quantity to protect or authenticate the contents of messages in support of financial transactions, and most especially in the field called Electronics Fund Transfer (EFT) because of demonstrated vulnerability to costly fraud.

(U) But, although a Government endorsed technique has now been on the street for a number of years, there has as yet been no rush to acquire equipments in quantity. This may be due, in part, to significantly lower perceptions of threat on the part of prospective customers than projected by ourselves and others. It may also stem, in part, from the slowness with which supporting Government standards and guidelines are being published (for Interoperability, Security Requirements, etc.)

(U) In any event, production and marketing of equipment by U.S. commercial vendors is not our biggest problem with public cryptography because there are various Government controls on such equipment - particularly, export controls - and Industry itself is usually disinterested in publishing the cryptanalytic aspects of their research in any detail. The central issue that continues to fester is encapsulated in the phrase: "Academic Freedom *versus* National Security."

(U) Our Director has made a number of overtures to various academic forums and individuals in an effort to de-fuse this issue, but has stuck to his guns with the statement that unrestrained academic research and publication of results can adversely affect National Security. While a few academicians have been sympathetic, the more usual reaction - at least that reaching the press - has been negative.

(C) The principal reason that there is an NSA consensus that unrestrained academic work has a potential for harm to our mission is because, if first-class U.S. mathematicians, computer scientists, and engineers begin to probe deeply into cryptology, and especially into cryptanalytics, they are likely to educate U.S. SIGINT target countries who may react with improved COMSEC. Less likely, but possible, is their potential for discovering and publishing analytic techniques that might put some U.S. cryptosystems in some jeopardy.

(U) The academicians' arguments focus on absolute freedom to research and publish what they please, a rejection of any stifling of intellectual pursuit, and concerns for the chilling effect of any requests for restraint. Their views are bolstered by the real difficulty in differentiating various kinds of mathematical research from "crypto-mathematics" - notably in the burgeoning mathematical field of Computational Complexity, often seeking solutions to difficult computational problems not unlike those posed by good cryptosystems.

~~(C)~~ As a practical matter, Government "leverage," if any, is rather limited. We have made some half-hearted attempts to draw an analogy between our concerns for cryptology with those for private research and development in the nuclear weapons field which led to the Atomic Energy Act that does - at least in theory - constrain open work in that field. But there is no comparable public perception of clear and present danger in the case of cryptology and, despite the "law," academicians have sanctioned research revelatory of atomic secrets including publications on how to build an atomic bomb.

~~(C)~~ Another wedge, which as yet has not been driven with any appreciable force, is the fact that - overwhelmingly - the money underwriting serious unclassified academic research in cryptography comes from the Government itself. Among them are the National Science Foundation (NSF), the Office of Naval

Research (ONR) and the Defense Advanced Research Projects Agency (DARPA). NSA supplies a little itself. The wedge is blunted because Government officials administering grants from most of these institutions have been drawn largely from the academic community who believe strongly in the value of research performed outside Government, and are sympathetic to concerns about abridgement of Academic Freedom.

(E) In the long run, balancing out our mutual concerns will probably depend more on the good will of influential sections of the Academic Community itself than on legislative, monetary or other control over cryptographic research in the private sector. It turns out that at least some governing bodies in various colleges and universities seem more ready to recognize some academic responsibility with respect to national security concerns than do many individual "young Turk" professors or their collective spokesmen who see Academic Freedom in First Amendment terms as an absolute. A good deal of the Director's quiet work on the matter appears to be oriented towards constructive dialog with responsible officials and groups.

(S) I have dwelt on the matter of public cryptography at some length because it portends some radical changes in our relationship with the public sector - more openness, dialog, controversy, and debate. Obviously, our conventional shield of secrecy is undergoing some perforation. In contrast, it might be worth noting that we have yet to see a single unclassified document from the USSR on their cryptography - not one word. (As a result, we spend small fortunes acquiring data comparable to that which realities suggest we must continue to cough up for free.)

(U) Nonetheless, I believe we can identify and continue to protect our most vital interests - our "core secrets" - and, meanwhile, dialog with intelligent people - even "opponents" - will surely expand our own knowledge and perspective.

(E) A more tangible outgrowth of public cryptography could be the infusion of commercial equipment in Government for the first time since World War II. As noted earlier, the votes are not yet in on how prevelant that may be; but it bodes new sets of problems in standards, doctrine, maintenance, protection, configuration control, cost benefit analyses, and secrecy.

(E) Consider the problem if a vendor offers to sell [redacted] highly secure equipment to the Government - perhaps one already supplied elsewhere - [redacted]

[redacted] How do we say no? I expect we'll just have to say it without elaboration [redacted]
[redacted]

(U) How do we offer a reasonable COMSEC education to U.S. users in unclassified environments without educating the world?

(E) How do we underwrite, endorse, certify, approve or otherwise sanction products in the abstract when their real security potential may well lie in how they are applied in a systems complex, not just on a good algorithm? Or how, alternatively, do we find the resources required to assess dozens of different devices in hundreds of different applications?

(U) We are currently wrestling with all these questions; but most of them will be incompletely answered for a long time. It may be useful for you to keep them in mind as you get involved with public cryptography downstream.

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(E) One of the more interesting outgrowths of the burgeoning interest in cryptography in the private sector was the "invention" of a concept called "Public Key Cryptography" (PKC). All conventional cryptography requires the pre-positioning of shared keys with each communicant. The logistics for the manufacturing and delivery of those keys keeps S3 in business and forces users to maintain a large secure crypto-distribution system. (Remote keying eases but does not eliminate the problem.) The thought was, cryptography would be revolutionized if a system could be devised in which people could communicate securely without prior exchange of keys.

(U) The main idea that came forward was an effort to capitalize on the fact that some mathematical functions are easy to carry out in one "direction," but difficult or impossible to reverse. A classic example of these so-called one-way functions is the phenomenon that it is not hard to multiply two very large prime numbers together, but given only their product, no elegant way has been put forward for determining what the two original numbers were.

(U) So the original numbers could be considered to be part of one man's secret "key;" their product could be published; an encryption algorithm could be specified operating on that product which could not be efficiently decrypted without knowledge of the "key"; and all messages addressed to that person would be encrypted by that algorithm.

(S) By coincidence, the identical idea had been put forward by one of our British colleagues five years earlier, and we and they had been studying it ever since. We called it non-secret encryption (NSE) and were trying to solve the same problem of key distribution. We treated our work on it as SECRET and still do. We did not leap to its adoption for a variety of a reason. Foremost, we were uncertain of its security potential. The fact that mathematicians had not yet found a way to factor large numbers did not mean that there was no way.

(U) It was an interesting mathematical puzzle, first put forward centuries ago, but with no great incentives for its solution beyond the satisfaction of intellectual curiosity, no perceived commercial applications, and so on. So there was no evidence of a great many brains having worked the problem over the years; nor did we go all out against it because, apart from theoretical doubts, there were other drawbacks.

(E) The most obvious - although perhaps not the most important - was the fact that the encrypter himself could never decrypt his own message - he would be using the cryptosystem of the recipient who was the only one holding the secret decrypting key - he would have no means to verify its accuracy or correct an error. More or less elaborate protocols involving hand-shaking between the communications were put forward to get around this difficulty - usually entailing the receiver having to re-encrypt the received message in the sender's key and asking if that was right. A clumsy business.

(E) Next, each user would have to keep his primes absolutely secret, forcing on each some of the secure storage and control problems inherent within conventional schemes. Known (or unknown) loss would compromise all of his previously received messages. To get around that, relatively frequent change would be necessary. This would move him towards the conventions of keying material supersession; generation and selection of suitable primes and their products, and their republication to all potential correspondents.

(E) Next was the matter of efficiency. The "key" would have to be on the order of 1000 bits long to make factorization difficult (or impossible?). Inherent in the scheme is the requirement to use all of that key for any message, however short. Further, a single garble renders the entire message unintelligible.

(U) In the more detailed schemes outlined so far, generation and manipulation of very large numbers is required, including raising them to some as yet undetermined power - but clearly more than just squaring them - and this leads to great complexity in any real implementation of the idea.

(C) Finally, there is the problem of spoofability. Anyone can send you a message in your key which you must either accept as valid or authenticate somehow. If I inject myself in your communications path, I may purport to be anybody, supply you my key, shake hands like a legitimate originator and lead you down various garden paths indefinitely.

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(e) So we are not yet prepared to accept PKC as a wave of the future. However, it continues to offer intriguing possibilities, particularly for short messages resupplying conventional keys among small user sets, and we may eventually find some use for it if we can do so without creating problems at least equal to those it is designed to solve.

COMPUTER CRYPTOGRAPHY

(S) Since most crypto-equipments these days can be viewed essentially as hard-wired special purpose computers with "programmable features" to accommodate variables, there has been considerable effort, dating at least to the early '60's, to use general purpose (GP) computers to do cryptographic functions - programming the whole process, encryption algorithm and all. The idea was particularly attractive at installations where some GP computer with excess capacity was already in place. The first operational system I recall was used to decrypt telemetry from the Navy's first position location satellite - the Transit system, in a shipboard computer, the BRN-3, implemented in 1963. Since the computer was required anyhow to carry out navigational calculations based on data received from the satellite, since it operated in a receive only mode (the sender was a conventional black box in the satellite), and since operation was "system high" (i.e., all personnel with access to any part of the computer were fully cleared for all the data being processed), no big computer security problems were involved - rather, it was a technical matter of programming cryptography efficiently into a system not originally designed to carry out such functions.

(C) Nevertheless, there has been little proliferation of computer cryptography in the ensuing years, mainly because the inherent constraints in the BRN-3 environment (excess capacity, system high operation, receive mode only, and rigorous access control) are still not prevalent. The security problems that arise when one or more of those limits disappear are difficult indeed. If, as is increasingly the case these days, the computer can be remotely accessed by various subscribers, the difficulty is greatly compounded. This is true because the vulnerability of sensitive data in a computer to inadvertent or deliberate access, extraction, pindown, disruption, tampering, misrouting, or other manipulation increases as you increase the opportunities for physical or electronic access to it. In this respect, the problem of insuring the security integrity of cryptographic information in a computer is no different than with "computer security" in general. As you no doubt know, that general problem is being assaulted on many fronts today with efforts to make "provably secure" operating systems, the development of the "security kernel" concept, kernelized virtual machines and so on. The threats are so numerous that a 247 page document ("ADP Security Design and Operating Standards", by Ryan Page) is still not definitive.

(C) Not the least of our worries with computer encryption proposals is the question of how to evaluate their security potential, how to validate large software programs such as you would need to implement, say, SAVILLE in software; and how to insure that "peripheral" changes elsewhere in the computer will not affect the integrity of the cryptography. It turns out, naturally enough, that S6 proceeds with diminishing confidence as systems become more complex, and with more and more functions not under the cryptographic designer's control which yet may affect the way the cryptography works. Control functions, timing functions, switching functions, etc., are typical examples of these "peripheral" activities that don't remain static - i.e., aren't hard-wired - and subject to change to facilitate other functions in the computer as time goes by.

(C) Two other factors have slowed the rush towards computer cryptography. The first is that most commercially available computers still have TEMPEST problems. Few meet our TEMPEST standards for crypto-equipments (KAG-30), and they are difficult to fix. The other factor is that the dedicated (special purpose) computer - an ordinary cipher machine, for example - can always carry out a single job more *efficiently* (space, speed, power consumption, and so on) than one with multiple functions.

(U) None of this means we can't do it - but we aren't there yet. And it's just possible that it's another of those waves of the future that will dissipate in the sea of time.

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POSTSCRIPT

~~(C)~~ It seems to me that NSA does not yet have much expertise in computer security. Rather, we are expert in computer insecurity. We do much better in finding security vulnerabilities in any computer complex than in proposing security architectures for them. Somehow, the attack seems more challenging (fun) than the defense, and this seems true in the general business of cryptosystem design as well. A spin-off of this syndrome manifests itself when a security modification is needed for an existing crypto-equipment. In my experience, most design engineers would *much* rather attack a brand new problem - meet a new and difficult requirement - starting from scratch, pushing the electronic state of the art, exercising opportunities for innovation, and so on than go through the drudgery of a mere "fix" accepting all the constraints of configuration and technology in some pre-existing piece of hardware.

(U) Or so it often seems to someone trying to whip up some enthusiasm for a change.

~~(C)~~ In any event, it seems true that for those of us involved in laying on requirements (be it equipments, modifications, destruct or erasure techniques, anti-tampering features, or whatever) there is no more important step we can take than to get the prospective design engineer (and, ultimately, management) to understand and *believe in* the project. The slow pace of destruct technology is perhaps a classic example where the physical security people in S have failed to convince R! and to some extent our own management that we've got a problem. But I think we do.

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TEMPEST UPDATE

(C) TEMPEST difficulties seem to whipsaw us more than any of the other technical security problems we have. Each time we seem to have achieved a reasonably well-balanced and managed program in NSA, other Agencies, and in the Industrial TEMPEST Program (ITP), some new class of problems arises. Better detection techniques call some of our older standards into question. New phenomena or variations of old ones are discovered. New kinds of information processors come into the inventory from the commercial world posing different suppression problems. Vulnerabilities remain easier to define than threat in most environments, and we seem to wax hot and cold on how aggressively the whole problem should be attacked.

(S-NF) The proliferation of Cathode Ray Tube display consoles (CRT's) is among the more recent examples to catch our attention and that of our customers. Most computers and their peripherals still come off the shelf from Industry without much TEMPEST protection built in. Customers may lay on tests after installation and if they see problems in their particular facilities, may try to screen them or, if threat perception allows, take their chances on hostile exploitation. But with CRT's, two things happened. First, they were more energetic radiators than most other information processors unless TEMPEST suppression (at greater cost) had been applied during manufacture. Second, the results of testing of an insecure device were horribly obvious. Testers, instead of having to show some skeptical administrator a bunch of meaningless pips and squiggles on a visicorder and esoteric charts on signal to noise ratios, attenuation, etc., could confront him with a photocopy of the actual face of his CRT with the displayed data fully legible, and could demonstrate instantaneous (real time) recovery of all of it from hundreds of yards away. This gets their attention.

(C) However, as seems to be the case with many of our more dramatic demonstrations of threat or vulnerability, the impact is often short-lived, and the education process soon must start again. But, despite the apparent fluctuations in threat perception and correlative command interest, the resources in R&D and personnel committed to TEMPEST problems in NSA and the Services remains fairly consistent, with between three and five million dollars expended in R&D each year, and with about 250 people engaged in TEMPEST work.

(S) It's fair to conclude that the problem will be with us as long as current flows, but the earlier judgment that we have it reasonably well in hand except in unusually difficult environments may have been too sanguine. We are being faced with more and more types of sophisticated information processors - including computer-based systems - and these are proliferating at a greater rate than we can track. This fact, coupled with more widespread knowledge of the phenomenon, the decline in the availability of trained technical personnel for testing and corrective action in the field (some test schedules have fallen as far as two years behind), and the advent of more potent exploitation devices and techniques place us in a less than satisfactory posture.

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SFA REVISITED

(C) "SFA" used to stand for "Single Failure Analysis." In the early 70's, a somewhat more elegant but less precise meaning arose - "Security Fault Analysis." It is a systematic process for examining the embodiment of a cryptologic to determine the security effect of malfunction or failure of individual components, switches, circuits, registers, gates and the like. Its purpose is to assure that any fault which would have a catastrophic effect on systems security is safeguarded against - usually through redundancy in design or some kind of alarm.

(C) A classic example of catastrophic failure is one which allows plain language being encrypted to bypass the key generator altogether and be transmitted in the clear. Another - usually more insidious - is a failure in randomizer circuitry causing predictable or repetitive initial set-ups for a machine.

(S) SFA had its beginnings with relatively simple electro-mechanical devices where pins might stick, switches hang up, or rotors fail to move, and no truly systemized examination for such failures was carried out or necessary. Most of those failures were not visualized and prevented during design. Rather, when they cropped up in the field and were reported, we would have to go back and retrofit. We had, for example, a case with a duplex one-time tape circuit where an operator noticed that an exact copy of his outgoing traffic was being printed, in the clear, on his receive teletypewriter. He thought a previous operator had jacked that teleprinter in to provide a monitor copy to assure accuracy of his send traffic. What had really happened was a simple failure of a Sigma Relay at the distant end of the circuit which caused the incoming messages, after decryption, to not only print out normally on his receiver but also to be shunted back, in the clear, over his send line. In another case, an on-line rotor system called GORGON seemed to be operating perfectly all day long when an operator noticed that the familiar clunking sound of moving rotors seemed to be missing. He lifted the lid to the rotor basket and discovered why. There were no rotors in it. Ordinarily, that would have caused continuous garble at the distant end, and the operator there would have sent back a BREAK to stop transmission. In this case, however, the distant end had *also* forgotten to put the rotors in, and so received perfect copy in the clear, but believed it to be decrypted text.

(C) But as we moved to complex electronic devices, some of which perform 25,000 or more discrete functions (the TSEC KG-30 family, e.g.) SFA evolved into a difficult, time-consuming, and costly process - viewed by some as an art, and an arcane one at that.

(S) For some years, the relationships between system designers and system evaluators involved in SFA could not be characterized as particularly cordial. With the advent of solid-state technology, designers were able to achieve extraordinary reliability for most of our devices; and some of them, therefore, tended to believe that the costly and meticulous SFA process was superfluous. They might well be able to demonstrate statistically that a given failure was likely to occur only once in, say, a decade. Adding tens or hundreds of dollars to the cost of each equipment to meet such contingencies seemed unnecessary. The security analysts, on the other hand, would point out that with our equipments now projected to remain operative for 20 years (vice the 15 year rule of thumb in former times), the probability of failure sometime in the equipment's life was very high. They noted further that, if the failure was the type that does not interfere with operations and is undetectable in routine maintenance, the equipment would keep running in an insecure mode for the rest of its life. And so the issue was joined with, I regret to report, some acid exchanges between analysts and project engineers.

(C) It worked out alright, though. For their part, the analysts began to get more precise about what constituted a critical failure. The designers meanwhile, through systematization of the process during equipment manufacture, found ways to anticipate problems and avoid some of the back-fitting which had previously been necessary. As is usually the case in our business, when security requirements conflict with cost in time and money, a fairly pragmatic trade-off is made. We have yet to build a machine deemed perfect from the security analysts' viewpoint, and I doubt we ever will. On the other hand, we've made few if any equipments against which security design overkill has not been asserted by its builders or the budget people, or both.

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NESTOR IN VIETNAM

(S) Most US SIGINT assets in Vietnam used NESTOR heavily and successfully almost from the outset. Towards the end of the war, so did most in-country Naval forces, particularly airborne assets. In the SIGINT user's case, it was because they were already equipped when they got in country; had used it previously, knew, accepted, or circumvented its peculiarities, and, of course, because they believed their traffic required protection. In the Navy case, it was the result of Draconian measures by the Commander, Naval Forces, Vietnam (COMNAVFORV). That Admiral happened to be a COMSEC believer; so he told his pilots that if they didn't use the equipment, he'd ground them. Some didn't, and he did. There is, I understand, no comparable trauma for a fighter pilot.

(U) The story with most of the rest of the "users" was quite different, and very sad. The reasons and excuses were manifold, and a few will be treated here for what might be learned from it.

(C) It was claimed that NESTOR reduced radio range. In an environment where communicators were only marginally able to reach one another anyhow, this was intolerable. Experiments at NSA before the equipment was deployed, and repeated investigations when these claims persisted, verified that NESTOR did not reduce range. They even showed that the system could sometimes enhance communications by holding higher voice quality (less noise) towards range limits; although when it reached the limit, loss of all intelligibility was abrupt and categorical.

(C) Finally, our own engineers sent to Vietnam reported back: "Sorry about that, S2; the system reduces range - typically by 10% or more." And it, in fact, did. It turned out that NESTOR did not affect range only if the associated radio was perfectly tuned, "peaked," matched to the NESTOR equipment (as we naturally did here at home). In the field, maintenance personnel were neither trained nor equipped for such refinement - the test instrumentation simply did not exist there, and we had not anticipated those real world conditions when we sent it out.

(C) In tactical air, it was claimed that the sync delay - up to 3/5 of a second of required wait between pushing to talk and ability to communicate - was intolerable when air-to-air warnings among pilots had to be instantaneous. A survey showed, by the way, that most pilots judged this time to be on the order of three seconds; so, in fact, the wait must have seemed interminable when one wanted to say "Bandit at two o'clock."

(C) Carrier-based aircraft ultimately adopted what was called a "feet wet-feet dry" policy in which they would operate exclusively in cipher while over water, but once over land, would revert to plain language. For Air Force pilots, it was not so much of a problem. They managed to install so few equipments in their aircraft, that they were able to create few viable crypto-nets, so most of them were in clear all the time.

(C) Navy had managed to jury-rig NESTOR (KY-28) equipment in essentially every carrier-based fighter aircraft they had. In the case of the F4 they found a nook inside the nose-gear housing, and tucked it in there. But the Air Force opted to go into a major aircraft modification program to accommodate the system, penetrating the skin and with elaborate wiring to remote the system to the cockpit. This took years. The problem was compounded because when aircraft did get in country with NESTOR's installed, they were periodically recalled to CONUS for maintenance and rehabilitation, took their NESTOR with them as part of the avionics package, and were replaced with unequipped planes.

(C) The ground version of NESTOR (KY-8) would not run in high ambient temperature. True. And there was plenty of such temperature around in Vietnam. There was an inelegant but effective solution to that one. The equipments were draped with burlap and periodically wetted down. So much for our high technology.

(C) There was a shortage of cables to connect NESTOR to its associated radio. This sounds like a small and easily solvable difficulty; but it turned out to be one of the biggest and most persistent we had. It stemmed from a deeper logistics problem because different organizations were responsible for fielding the various components that went into a secure tactical system. We procured the NESTOR equipment. Various Service organizations procured the various radios with which it was used; and still different organizations fabricated cables and connectors to link them up. Systems planners and implementers in Vietnam eventually

gave up and appealed to CINCPAC to orchestrate a coherent program. CINCPAC gave up and appealed to JCS (who may have done a staff study), and it was never solved.

(E) Some NESTOR users had AM radios, some FM, and ne'er the twain would meet even though they were cooperating forces.

(E) Over the length and breadth of South Vietnam were many cryptographically unique NESTOR nets (i.e., different key lists) to comply with doctrinal rules limiting net size because of the high vulnerability to compromise of keys in that environment. The limit started out at about 250 holders, was extended to 400, and we eventually tolerated a country-wide net for air-to-air/air-ground communications to accommodate aircraft which might show up anywhere.

(E) The manpack version (KY-38) was too heavy - KY-38 plus PRC 77 radio, plus batteries, plus spare batteries weighed about 54 pounds. The Marines, especially, tried to overcome this, even going so far as to experiment with two-man carries, one toting the 38, the other the radio, and with a cable between them. As you might imagine, that worked none too well in the jungle, and I believe most of them decided that carrying ammunition would be more profitable for them.

(E) NESTOR is classified, people fear its loss, careers may be in jeopardy, and it was safer to leave it home. This Unicorn - this mythical beast - was the most aggravating, persistent, elusive, and emotional doctrinal issue to come out of that war. We sent emissaries to a hundred locations. We found no qualms about associated keying materials always with the equipment, and which were almost always more highly classified than the equipment itself. We found no concern over keyed CIRCE devices issued in well over 100,000 copies; and we found another CONFIDENTIAL tactical equipment, KW-7, used with enthusiasm as far forward as they could get power. Our records show that the exact number of NESTOR equipments lost as a result of Vietnam was 1001, including a number that were abandoned when we were routed, but mostly in downed fixed wing aircraft and choppers, and in overruns of ground elements. We found no evidence of "disciplinary" action because somebody lost a NESTOR while trying to fight a war with it, nor, in fact, for any other cause. Yet, "classification inhibits use" remains a potent anti-classification argument for all crypto-equipment to this day.

(S) The argument in the Vietnam context came as close to being put to rest as I suppose it ever will be by a major CINCPAC study published in 1971. By that time the matter of non-use of NESTOR had become a burning issue. Here, an expensive crash program had been undertaken by NSA to build and field 17,000 KY-28's and 38's; a bonus of \$3 million had been paid for quick delivery. The total NESTOR inventory exceeds 30,000, yet best estimates in 1970 suggested that only about one in ten of the devices was being used. A questionnaire was administered to about 800 individuals who had had some exposure to the system in SEA. It contained a dozen or so questions, all oriented towards determining why the system was not being used more heavily. Some of the more relevant findings are quoted below:

(E) How do you feel that the use of tactical secure voice equipments affects the operations of your unit?

- 1—Speeds up and improves operations
- 2—Slows down and interferes with operations
- 3—Has little or no affect on unit effectiveness

	Answer No. 1		Answer No. 2		Answer No. 3	
	Number of Responses	Percent of Total	Number of Responses	Percent of Total	Number of Responses	Percent of Total
Overall	463	58.5	173	22.0	152	19.2
Army	220	78.9	23	8.2	36	12.9
Navy	99	68.2	25	17.5	19	13.3
Air Force	199	37.1	118	36.8	84	26.2
Marines	25	55.6	7	15.6	13	28.9

(E) Listed below are a number of factors which might tend to cause responsible persons to avoid taking TSV equipments into combat or simulated combat. Rank them (and any others you may wish to add) in the order of their importance to you.

A—My military career might suffer if I were judged responsible for the loss or compromise of cryptographic material.

B—The enemy might be able to recover lost equipment and keying materials and might then be able to read U.S. TSV traffic.

C—If my TSV equipment were lost at a critical time, its unavailability might reduce the operational capability of my unit.

D—The TSV my unit uses most must be *carried* into combat and is so heavy that it slows down our mobility.

E—Other (Specify)

	A	B	C	D	E	
Overall	45	266	87	63	29	Figures shown are first choices
Army	24	113	43	47	5	
Navy	7	31	19	0	3	
Air Force	13	104	21	3	10	
Marines	1	18	4	13	1	

(C) If you use TSV equipment in combat, simulated combat, or other hazardous circumstances, does your concern about its possible loss or compromise restrict its operational use or usefulness?

1—Yes, to a considerable degree

2—To some moderate degree but not significantly

3—No

	Answer No. 1		Answer No. 2		Answer No. 3	
	Number of Responses	Percent of Total	Number of Responses	Percent of Total	Number of Responses	Percent of Total
Overall	46	7.7	97	16.3	451	75.9
Army	30	13.6	57	25.9	133	60.5
Navy	2	2.6	10	13.0	65	84.4
Air Force	7	2.9	2	0.8	229	96.2
Marines	7	17.9	8	20.5	24	61.5

(C) Listed below are a number of possible operational disadvantages which have been raised with regard to the use of TSV communication and identify their importance to you.

A—Inability of TSV-equipped stations to communicate in cipher with all desired stations.

B—Occasional interruption of communication due to loss of synchronism between the transmitting and receiving stations.

C—The time delay required to synchronize the sending and receiving crypto-equipments is intolerable in some type of military activity.

D—The size and weight of the TSV equipments and their power supplies is prohibitive in some situations.

E—The application of TSV equipment to UHF, VHF-AM, and/or VHF-FM tactical radio circuits/nets reduces seriously the effective ranges.

F—An unacceptable level of maintenance problems are associated with the operation of TSV equipments.

G—TSV equipment is not reliable in critical situations.

H—Unacceptable physical security restrictions are associated with the use of TSV equipments in the field.

I—Other (Specify)

	A	B	C	D	E	F	G	H	I
Overall	223	115	46	54	31	18	28	13	12
Army	72	43	7	39	10	11	1	5	2
Navy	41	31	6	1	7	3	7	3	4
Air Force	101	35	30	4	14	4	20	4	4
Marines	9	6	3	10	0	0	0	1	2

(C) From the NESTOR experience, and the antithetical experience with ORESTES and other systems in much the same environments, it might be concluded that the overriding criteria for the acceptance or failure of our equipment offerings are whether there is a perceived need and whether they do what they're supposed to do - they work - reasonably well without inhibiting operations.

EMERGENCY DESTRUCTION OF CRYPTO-EQUIPMENT

(C) Except in a tiny number of locations where the user can afford the luxury of large powerful disintegrators that chew crypto-components into little pieces, we remain dependent on World War II pyrotechnic technology to get rid of crypto-equipments in a hurry in an emergency. Meanwhile, the environments into which the equipments are now being deployed are increasingly hazardous in peace time and in war. Further, when we ruggedize hardware we aren't kidding, having fielded some of the most indestructible boxes in the world. Some seem at least on a par with flight recorders that survive the most catastrophic of crashes.

(C) A crashed helicopter in Vietnam caught fire and reduced itself to not much more than slag. Its NESTOR equipment was fished out, cleaned up, and ran perfectly. More recently, a telemetry encryption equipment (KG-66) on a missile shot at White Sands ran perfectly after being dug out of the 8 foot hole created at impact.

(C) Chip technology compounds the problem. The chips are so small that they'll often filter through a disintegrator unscathed. Conventional pyrotechnics don't help because their melting temperature is typically 2800° F.

(S-NF) Meanwhile, the new environment? When Volume I was written, the only case in US history of the invasion of an Embassy was by mob in Taipeh in 1957. There were no destruct facilities and, had there been, then as now, the whole building would have gone up in smoke had pyrotechnics been used. So - again then as now - reliance was on the vault. Since the mob could not penetrate its big steel door, they knocked a hole in the adjacent wall, stormed into the crypto-center, and scaled rotor and other cryptomaterial down to the crowd below. About 50 of the 100 or so rotors were not seen again. Since those days, no less than 32 (counting MAAG, the total is near 50) U.S. facilities (embassies, legations, missions) containing crypto-equipment have come under attack, 13 of them during the 6 Day War in the Middle East, 7 more in Iran during the revolution, another incident with the re-invasion of the Embassy when the hostages were taken, other assaults in Islamabad and Tripoli, and an attempt on our Embassy in Beirut.

(S-NF) In all, in the first Iranian crisis, 7 different types of crypto-equipment were jeopardized, totalling some 65 pieces of hardware. Precautionary evacuation and emergency destruction efforts ranged from total and sometimes spectacular success, to complete failure in one installation where two types of equipment had to be left up, keyed, running, and intact. It became clear that our destruct capabilities were inadequate or useless where we had little warning, and hazardous at best even where warning or a good vault offered time to carry out the procedures. Fire could lead to self-immolation in the vaults; shredders and disintegrators depended sometimes on outside power which was cut off; and smashing of equipments could render them inoperative, but not prevent the reconstruction of their circuitry.

(S) Correlatively, our traditional policy for limiting the use of crypto-equipments in "high-risk" environments was quite evidently wanting. That policy generally called for deployment of our oldest, least sensitive, and usually, least efficient systems in such environments. The effect was to deny people in the field good equipment in crisis, just when they needed it most. This was particularly true of secure voice equipment to report events, and effect command and control when installations were under attack.

(C) What seems needed is some push-button capability to zap the equipment, literally at the last moment, allowing secure communications until the facility must be abandoned, and not dangerous to the button pusher.

(S) The most successful use of pyrotechnics (thermate slabs, thermite grenades, and sodium nitrate barrels) in Teheran occurred at the major Army Communications Center there. It had a number of crypto-equipments, but also served as a depot for pyrotechnic materials for the whole area. They piled all of their classified cryptomaterial in a shed; covered them with their pyrotechnic material (some 300 devices), lit off the whole enchilada, and took off. The result was probably the largest single conflagration during the entire revolution. Observers reported seeing flames shooting hundreds of feet into the air from posts several miles away. The building was, of course, consumed, and we assume only a slag pile remains. (At this writing, about 15 months later, no American has been back.)

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(S) Despite all of the above, we have not been altogether inert on the matter of emergency destruction over the past decade or so. Each catastrophe seems to have stimulated at least a brief burst of effort to find a way. When the Pueblo was captured, we found that our best laid emergency destruction plans had gone awry. There was a shredder and an incinerator on board, and a few axes and sledges. In those days, Navy ships were not permitted to carry pyrotechnic destructors because of their fire hazard. Considerable reliance was placed on jettisoning material; but in the Pueblo case, the crew could not get to the side without being machine-gunned. We had, in any event, become increasingly skeptical of jettisoning as a viable way to prevent the recovery of equipment as various submersibles attained greater and greater depths. We also found to our astonishment that some of the electronic crypto-equipments built in the fifties (and sixties) float.

(S) Our first major customer for a safe and reliable means for emergency destruction on shipboard was, as you might expect, another intelligence collector [redacted] S2 was allowed to fabricate some boxes (on a not-to-interfere with COMSEC work basis) which would incinerate material while containing the heat and flame. Some research was carried out, again under S2 aegis, to build or modify ordinary safes to destroy their own contents. Work came to a virtual halt, however, when a disgruntled contractor whose proposal had been turned down raised an unholy stink with our Director, senior officials in the Defense Department, and sundry Congressmen. (Congressional inquiries, we have discovered, can sometimes have a chilling effect.)

(E) The upshot was that NSA and DoD decided that the *general* problem of destroying classified materials was not NSA's business - particularly with respect to the destruction of ordinary classified documents. We were directed to confine ourselves exclusively to techniques uniquely useful in the cryptographic business. The trouble was that there was no other Government Agency prepared to accept such a role. The Army Chemical Corps had provided the original pyrotechnic approaches to destruction but, as noted, had not done much since World War II except, at NSA behest, the development of the sodium nitrate in a barrel or hole-in-the-ground approach. There had been an agency created in the Department of Defense in its early days called the Physical Security Equipment Agency. It was an assemblage of physicists, chemists, and engineers with little security background and apparently, few practical ideas. They were abolished in December 1976, with no re-assignment of their functions.

(E) So, in 1976, DoD accepted the overall responsibility for destruction methodology, and assigned the Navy as Executive Agent to do the necessary research and development. As usual, they were underfunded and understaffed, and have been progressing very slowly. We, meanwhile, keep not much more than a man-year or two engaged in the special problems of crypto-equipment destruction. With our increasing reliance on micro-circuitry, someone had the idea of planting tiny, non-violent shaped charges in critical junctures in our circuits that could be triggered by the application of external voltage. The project became known as LOPPER, and R1 was charged to pursue it. The original equipment targetted for incorporation of the technique was VINSON. But, it would cost more, might delay the program and, again, did we really need it? So, R1 had developed the technique to the point of feasibility demonstration models; tests were run on circuit boards, were successful, and we stopped.

(E) We were damned again by the perception that this was a solution looking for a problem - exactly the same inhibitor which has slowed or killed nearly every new departure that costs something for which there is no *universally* recognized need. We (proponents of the desirability of protecting our hardware as best we can for as long as we can) had done it to ourselves when we began letting people know, as early as 1950, that the key's the thing; all those contrary arguments in the direction on classification notwithstanding. One set of curmudgeons in our business can insist that security is not free, that we are in the communications security not the communications economy business, while another set, with equal force, can state that the too-high security standards or demands are pricing us out of the market, leaving our tender communications altogether naked to the world.

(U) I suggest that newcomers to the business not jump on board whichever side of this controversy your viscera may first direct. Rather, take the other side - whichever it is - and go through the exercise of building its defense. You are likely to be surprised at how elaborate and involuted the arguments become either way and might lead you to my personal conclusion that the best way to achieve a net gain in our resistance to communications compromise is through compromise. Still, it seems that once in a while one

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ought stand on principle - as a matter of principle! - and hang tough where truly vital interests are concerned.

~~(C)~~ So, LOPPER came a-cropper, at least for a time. The "compromise" solution was put forward: if we can't afford to implant this technology in the whole product line, can't we at least build a limited quantity of circuit boards with the capability for deployment to high-risk facilities? The answer was no: small quantity production is far too expensive; you can't amortize the R&D and product costs. Turns out that there is a useful rule of thumb for most of our product line: unit cost drops 15-20% for each doubling of the number of procured.

(U) At the moment, we are in low-key pursuit of a variation of the LOPPER approach for some future systems. It involves burying a resistor in the chip substrates which will incinerate micro-circuitry with the application of external voltage. We'll see.

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POSTSCRIPT ON DESTRUCTION—DAMAGE ASSESSMENTS

(C) When major potential losses of cryptomaterial occur, damage assessments are called for - usually in a hurry; and particularly if the possibly compromising incident hits the press. Often, we will have 24 hours or less to make some kind of interim assessment of what may have been lost, in what quantity, with what probability, and with what impact on national security.

(C) Often in this hectic process, we start out with little more than what's in the newspapers but, because of our access to the records of the crypto-accounts involved, we are usually able to build a pretty good inventory of the materials involved within a few hours and, sometimes have information on the destruction capabilities at the site(s) involved. In first reports, what we rarely get is an accurate picture of the degree of the destruction actually achieved; so our initial assessments are invariable iffy.

(C) A principal lesson we have learned in formulating these assessments is patience - sometimes waiting many months before we "close" the case, meanwhile interviewing witnesses to or participants in the event, visiting the scene if we can get there, performing laboratory analyses of recovered residues of the destruction effort, and so on, before making a definitive declaration of compromise or no compromise, as the case may be.

(C) A second lesson has been that our first gut reactions have usually been wrong, erring equally on the optimistic and pessimistic sides when all the facts (or all the facts we're ever going to get) are in. Some materials have been recovered after many days, weeks, or months under hostile control with no evidence that they knew or cared what they had. In other cases, post mortems have shown losses to have been significantly more substantial than were suggested by the early "facts."

(C) Finally, we have found it prudent to treat damage assessments as exceptionally sensitive documents, for two reasons. The first is that they explain just what the materials are and how they could be exploited by a canny opponent. The second is that they reveal our own judgment on what was and wasn't lost. That information is important to any enemy, particularly if we were wrong, and he has been able to recover something we think he does not have.

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TRANSPOSITION SYSTEMS REVISITED

(C) In Volume I, it was noted that transposition systems were thrown out of our lexicon because they contained the seeds of their own destruction - all of the elements of plain language appear in the cipher text; they've merely been moved around with respect to one another. A jigsaw puzzle, in fact.

(C) Turns out, the same deficiency exists with equipments designed to destroy classified paper by shredding and chopping it into small pieces. The spectacle, in early 1980, of Iranian "students" occupying the US Embassy in Teheran, laboriously fitting together shredded materials comes to mind. In the destruction world, the problem was more or less solved by insisting that the pieces be so small and numerous that worlds of work would produce only fragmentary results.

(S) Our current standard - no destruction machine approved unless the resultant fragments were no larger than 1.2 mm x 13 mm (or 0.73 mm x 22.2 mm depending on the crosscut shredder used) was arrived at viscerally. But when the technology came along, we verified the standard by investigating the computer-assisted edge-matching or similar techniques which could see and remember shapes in a large display of small two-dimensional objects, and sort out those that fit together. As a result, we feel more comfortable about the question of whether such stuff can be reconstructed, however painstaking the attack. (As always, though, there are pressures to relax the standard, allow larger chunks because the finer the grain you demand, the more costly and time consuming the process. In a chopper, for example, you need more and finer blades, finer screens, and more cycling of the machine.) The material in Teheran by the way, was not from the crypto-center and was the product of a machine which we had specifically disapproved for our purposes.

(C) The transposition idea for cryptography did not stay dead with us. It had enormous attraction in the voice encryption business because if elements of speech could simply be arranged (transposed) in time and/or frequency, that would eliminate the need for digitization, which would in turn save bandwidth and still give good fidelity when it was unscrambled (untransposed). That meant enciphered voice of reasonable quality could be driven through narrowband transmission systems like ordinary telephone circuits and HF radio. Long-haul voice communications would be possible without large, complex very expensive terminals to digitize and still get the fidelity required.

(S) So, PARKHILL. Instead of making our fragments physically small as in a paper destructor, we made them small in time - presenting a brand new jigsaw puzzle each 1/10th of a second. Solvable? Sure. All you have to do is reconstruct 600 completely separate and quite difficult cryptograms for each minute of speech. We calculate that a good analyst might do a few seconds worth a day. Looks to be a risk worth taking - with that plain language alternative staring us in the face. We did, however, impose some limits in its use.

(S) We had never before fielded a less than fully secure crypto-equipment and, as our various caveats on its security limitations were promulgated, they sent some shock waves through the customer world and caused some internal stress in S. Our applications people quite rightly sought maximum use where plain language was the only alternative, while security analysts (also rightly) expressed continuing reservations on whether its usage could really be confined to tactical and perishable traffic - particularly as it gravitated increasingly towards wireline application rather than just HF radio for which it was originally designed.

(S) Part of the difficulty may have been that the only formal, objective crypto-security standard ever published in S is the High Grade Standard for equipments - systems meeting that standard are essentially approved for any type of traffic you might specify for their fifteen or twenty year life. No intermediate or "low-grade" standard has been adopted, despite yeoman efforts to devise one. Ironically, even among the high grade systems, there is considerable variation in their overall security potential - some provide transmission security; some do not. Some are heavily alarmed; some have little protection against failure. Some have full TEMPEST protection; TEMPEST standards were waived or moderated for others. The difference with PARKHILL may be that it is the first equipment from which at least fragments of plain language may be recoverable at lower cost and in less time than possible with any other equipment, even when it is working perfectly. But, again, remember, the alternative.

(S) A further irony is that while a real dilemma is seen with PARKHILL, we have accepted - mostly blandly - a large inventory of manual systems, many of which can be broken with relative ease. In their case, we have accepted, perhaps too uncritically, the idea that the systems themselves place limits on the

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kind of traffic they can process. At this writing, however, rumor has it that there is a sub-rosa paper authored by a fresh face entitled something like: "Manual systems - Are they Worth the Paper They're Printed On?" COMSEC will be well-served with critical re-examination of old ideas and quite a batch of hoary premises (including some in Volume I!), particularly by our new people. Just be sure of your facts.

MORE MURPHY'S LAW

(S) There have been occasions when we have had reason to suspect unauthorized access to various cryptomaterials which we could not prove. In these circumstances, if we can recover the material in question, we are likely to subject it to laboratory analysis to see if we can find evidence of tampering, unexplained fingerprints, and so on. One such case involved an operational T.S. key list being examined for latent prints in an S2 chemical lab. When the document was placed on a bench under the powerful blower system used to evacuate fumes at that position, this highly sensitive strictly accountable item was sucked up and disappeared into the elaborate duct-work system above the false ceiling.

(C) For NSA to have lost that keylist would have been a matter of acute embarrassment and there was, thus, considerable milling about. People were dispatched to the roof to check the vent with visions of our key list wafting somewhere about the wilds of Fort Meade. The vent was screened, however, and the document had not come up that far - it was somewhere in the bowels of the building in several hundred feet of ducting. GSA technicians arrived, and work was started from the bottom. At the first elbow, there was a small jam of paper, cotton, and cleaning rags, but no key list. About 20 feet along at another sharp bend, tin snips were used to open up the duct, and there was the document, snagged on some jagged protuberance. A relieved custodian clutched the document, and no compromise was declared.

(C) An automobile crashed in Texas and the trunk sprang open. State troopers found a suspicious-looking duffle bag and checked its contents. Hundreds of low-level Op-Codes and authenticators were inside. The driver claimed not to have known the material was there; the car belonged to his brother-in-law, a Sergeant who had been shipped to Vietnam a few months earlier. He was tracked down and, sure enough, had left the material in the trunk for the duration. He had evidently been on a run to the incinerator with a burnbag full of used materials, had run out of time, and shipped out leaving the chore undone. He claimed he intended to get rid of the stuff when he got back.

(S) Somebody moved into a small apartment near a Navy base in California. Far back on a top closet shelf he found a clip-board. On the board were two T.S. ADONIS keylists and several classified messages. The previous resident, a military man, had occupied the apartment only briefly, and swore he had never seen the material in his life. The origin of the keying material was traceable by short title, edition, and register number, and turned out to have been issued to a unit at Camp Lejeune.

(S) More research showed that a Marine Sgt who had had access to the material had been sent to the West Coast, and sure enough, had lived for a while in the apartment where the documents were found. He was located and admitted that he had squirreled the material away, and claimed he had then forgotten it. His motive? Simply that classified documents "fascinated" him.

(C) Strangely enough, this is a recurring theme. In this case, the polygraph seemed to bear him out, as it did in at least one other case where the identical motivation was claimed.

(C) KAG-1/TSEC used to be the bible of US cryptographers, was held in every crypto-center, and covered everything from message preparation to compromise reporting in considerable detail. While we viewed it as a model of clarity, this perception was not always shared in the real world. A frustrated Navy Chief stormed out of his crypto-center on board a carrier at sea, handed KAG-1 to a sailor and jokingly said "Throw this dam' thing overboard." He did. Several ships thereafter steamed back and forth for several days, but never found it. Winds, tides, and currents were studied to predict where it might come ashore with results so ambiguous as to offer little hope and, in fact, it was never recovered - at least by us.

(C) This incident triggered an R1 study on what happens to our documents in salt water. A tank was made, and a copy of KAG-1 immersed. It stayed there for a year or so with no sign of deterioration. Agitators were added to stimulate wave action for another few months, with still no appreciable effect. We never did find out how long such a document would last. Subsequent work, however, has shown that good paper is nearly impervious to salt water, apparently indefinitely. A visit to S2's exhibit of materials recovered from the sea bottom will bear that out. There you can see perfectly legible codes that had been under water since World War II, together with extraordinarily well-preserved items of hardware and magnetic tape that had been on the bottom for many years. These facts add to the previously expressed skepticism about

jettison as a way to get rid of our stuff unless at very great depths and in completely secret locations. (Shortly after WWII, small Army training crypto-devices called the SIGFOY were disposed of beyond the 100 fathom curve off Norfolk. Some years later, they became prize souvenirs for beach combers as they began washing ashore.)

(E) *UNSOLVED PUZZLE* - We used to store a lot of cryptomaterial in a warehouse at Ft. Holabird. It was fenced and protected by a 24-hour armed civilian guard. One evening, such a guard saw an individual inside the fence, evidently attempting to penetrate the warehouse. He drew his weapon, cried "Halt!" and led the individual to the guard shack and started to call in for help. About that time, the intruder started running, climbed the fence, and disappeared. We asked the guard why he didn't shoot - he said he was afraid he might hurt somebody. It was one of the few attempted penetrations we know of, and has never been resolved.

(E) *CONFETTI* - When we manufacture one-time tape, a by-product of the punching process is millions upon millions of tiny, perfectly circular pieces of paper called "chad" that come out of holes in the tape. This chad was collected in burn bags and disposed of. Someone thought it would make good public relations to give this stuff to high school kids for use as confetti at football games. Inevitably, one of the burn bags was not quite empty when the chad went in. At the bottom, were a couple of TOP SECRET key card book covers and a few assorted keys. They carried the impressive caveats of those days like "CRYPTO - CRYPTO-CLEARANCE REQUIRED" and were, to use a term earlier referred to, "fascinating" to the kids when they discovered them.

(E) One of the girls, whose father happened to be an Army officer, tacked some of this material on her souvenir board. When Daddy saw it, he spiralled upward. He decided that it must be destroyed immediately; but first made a photograph of it for the record. He tore it up, flushed it away, and reported in. With some difficulty, various cheerleaders and other students who had glommed on to some of this material were tracked down, and persuaded to part with it. We no longer issue confetti.

(E) We used to keep careful records of security violations in S, publicize them, and run little contests to see what organization could go longest without one. A retired Lt. Colonel wrecked SI's outstanding record as follows:

(E) He reported to work one morning and found one of those ominous little slips on his desk, asserting that a paper under his blotter carried a safe combination, and "requesting" him to report to Security at once. He was outraged - he had never been guilty of a security violation in his life; the safe combination was not his, nor did it match any safe in his office. He rushed out the door and down to the Security Office. They accepted his story, cancelled the "violation," and he returned to his office somewhat mollified.

(U) There, on his desk, was another violation slip. He had left his office door open when he reported to security, and that was against the rules. That one stuck.

(E) A (now) very senior official in S bent the rules by starting out to a conference in the Pentagon with some classified papers but without escort. He got as far as Foxhall Road in an ice-storm where he was confronted with a pile-up of cars that had skidded uncontrollably down into the hollow adjacent to the Girls' School there. He managed to slide to a stop without adding to the pile, got out, and immediately found himself in the path of a following car skidding toward him. To see him now, you would not believe that he made the only route to safety - over the seven foot chain link barbwire-topped fence around the school. He got some lacerations in the process, however, and someone took him to Georgetown Hospital for treatment. He refused to go, however, until he was able to flag down an NSA employee (our Adjutant General at the time!) to take custody of his classified materials.

(E) There have been, by the way, rather serious incidents involving classified materials in automobiles. In one case, an individual carefully locked a briefcase full of classified reports in the trunk of his car while he made a quick stop at a business establishment. The car was stolen while he was inside. So, watch it.

(E) When technical security teams "sweep" our premises, one of their chores is to examine conduits for extraneous wires, trace them out, or remove them. We had a peculiar case at Nebraska Avenue (the Naval Security Station at Ward Circle where various parts of the Agency were tenants from 1950 until 1968). An inspector on the third floor removed a floor access plate to examine the telephone wiring and saw a wire begin to move. He grabbed it, retrieved a few feet, then unknown forces on the other end began hauling it back. A tug of war ensued. Turned out that a fellow-inspector on the floor below was on the other end.

CLASSIFIED TRASH

(E) One day, back in the '60's, one of our people was poking about in the residue beside the Arlington Hall incinerator. The incinerator had been a headache for years: the screen at the top of the stack had a habit of burning through and then it would spew partially burned classified COMSEC and SIGINT materials round and about the Post and surrounding neighborhood. Troops would then engage in a giant game of fifty-two pickup. This day, however, the problem was different - the grate at the floor of the incinerator had burnt out and the partially burned material, some the size of the palm of your hand, was intermixed with the ash and slag.

(C) There was no way of telling how long the condition had persisted before discovery, so we thought we had better trace the ash to the disposal site to see what else was to be found. The procedure was to wet down the residue for compaction, load it on a dump truck, and haul it away. In the old days it had evidently been dumped by contractors in abandoned clay pits somewhere in Fairfax County (and we never found them); but the then current practice was to dump it in a large open area on Ft Meyer, South Post, adjacent to Washington Boulevard.

(E) Our investigator found that site, alright, and there discovered two mounds of soggy ash and assorted debris each averaging five feet in height, eight to ten feet wide, and extending over 100 yards in length. He poked at random with a sharp stick, and thought disconsolately of our shredding standards. Legible material was everywhere - fragments of superseded codes and keying material, intriguing bits of computer tabulations; whole code words and tiny pieces of text. Most were thumb-size or smaller; but a few were much larger. Other pokers joined him and confirmed that the entire deposit was riddled with the stuff. Some of it had been picked out by the wind and was lodged along the length of the anchor fence separating the Post from the boulevard.

(U) Our begrimed action officer was directed to get rid of it. *All* of it. Being a genius, he did, and at nominal cost. How did he do it?

(S) The solution to this problem was most ingenious - a truly admirable example of how a special talent combined with a most fortuitous circumstance eventually allowed us to get all that stuff disposed of. I won't tell you the answer outright: instead, I will try to aggravate you with a very simple problem in analysis of an innocent text system. Innocent text systems are used to send concealed messages in some ordinary literature or correspondence. By about this time, you may suspect that perhaps I have written a secret message here by way of example. That, right, I have! What's here, in fact, is a hidden message which gives you the explanation of the solution we accepted for disposing of that batch of residue. If we ever have to do it that way again, it will be much more difficult for us because the cost of everything has escalated, and I doubt we could afford the particular approach we took that time.

(S) If you are really interested in how innocent text systems are constructed, he advised that there are twenty-jillion ways to do it - every one of them different. Some of them may use squares or matrices containing an encoded text with their values represented by the coordinates of each letter. Then those coordinates are buried in the text. About another million ways - a myriad - are available for that last step. In fact, the security of these systems stems mostly from the large variety of methods that can be used and on keeping the method (the logic) secret in each case. Once you know the rules, solution is easy. So now, find my answer above - no clues, except that it's very simple, and one error has been deliberately incorporated, because that is par for the course.

UNCLASSIFIED

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NATIONAL SECURITY AGENCY
CENTRAL SECURITY SERVICE
FORT GEORGE G. MEADE, MARYLAND 20755-6000

Serial: MDR-54498

10 December 2008

This responds to your request of 23 December 2007 to have A History of U.S. Communications Security (2 volumes) by David G. Boak, Fort George G. Meade, MD National Security Agency, 1973 reviewed for declassification. The material has been reviewed under the Mandatory Declassification Review (MDR) requirements of Executive Order (E.O.) 12958, as amended and is enclosed. We have determined that some of the information in the material requires protection.

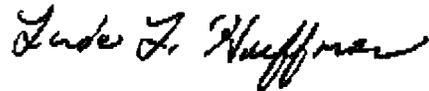
Some portions deleted from the documents were found to be currently and properly classified in accordance with E.O. 12958, as amended. The information denied meets the criteria for classification as set forth in Section 1.4 subparagraphs (c) and (d) and remains classified SECRET and CONFIDENTIAL as provided in Section 1.2 of E.O. 12958, as amended.

Section 6.2 (c) of E.O. 12958, as amended, allows for the protection afforded to information under the provisions of law. Therefore, the names of NSA/CSS employees and information that would reveal NSA/CSS functions and activities have been protected in accordance with Section 6, Public Law 86-36 (50 U.S. Code 402 note).

Since your request for declassification has been denied you are hereby advised of this Agency's appeal procedures. Any person denied access to information may file an appeal to the NSA/CSS MDR Appeal Authority. The appeal must be postmarked no later than 60 calendar days after the date of the denial letter. The appeal shall be in writing addressed to the NSA/CSS MDR Appeal Authority

(DJP5), National Security Agency, 9800 Savage Road, STE 6884, Fort George G. Meade, MD 20755-6884. The appeal shall reference the initial denial of access and shall contain, in sufficient detail and particularity, the grounds upon which the requester believes the release of information is required. The NSA/CSS MDR Appeal Authority will endeavor to respond to the appeal within 60 working days after receipt of the appeal.

Sincerely,

A handwritten signature in cursive script that reads "Linda L. Huffman".

LINDA L. HUFFMAN
Chief
Declassification Services

Encl:
a/s

~~COMINT~~

Declassified and approved for
release by NSA on 12-10-2008
pursuant to E.O. 12958, as
amended. MDR 54498

~~VII-26-X~~

A HISTORY OF U.S. COMMUNICATIONS SECURITY (U)
(The David G. Bank Lectures)

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INTRODUCTION

This publication consists of a series of lectures prepared and given to interns and other employees by Mr. David G. Boak in 1968. Mr. Boak is uniquely qualified to discuss the history of U.S. COM-SEC because he has participated significantly in most aspects of its modern development over the past twenty years.

The purpose of these lectures was to present in an informal yet informative manner the fundamental concepts of Communications Security and to provide an insight into the strenghts and weaknesses of selected manual systems, electro-mechanical and electronic crypto-equipments.

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FIRST LECTURE: The Need for Communications Security

I will spend most of this first period belaboring some seemingly obvious points on the need for communications security; why we're in this business, and what our objectives really are. It seems obvious that we need to protect our communications because they consistently reveal our strengths, weaknesses, disposition, plans, and intentions and if the opposition intercepts them he can exploit that information by attacking our weak points, avoiding our strengths, countering our plans, and frustrating our intentions. . . something he can only do if he has advance knowledge of our situation. But there's more to it than that.

First, you'll note I said the opposition can do these things *if* he can intercept our communications. Let me first give you some facts about that supposition. You've all seen the security caveats asserting that "the enemy is listening", "the walls have ears", and the like. One of my irreverent friends, knowing where I work, insists on referring to me as "an electronic spy", and popular paperback literature is full of lurid stories about code-breakers and thieves in the night careening to Budapest on the Orient Express with stolen ciphers tattooed somewhere unmentionable. What is the actual situation?

[redacted]

[redacted] their collection facilities include large land based sites, mobile platforms (air and sea), and satellite surveillance; and that they have an extensive covert collection operation. All in all, a truly formidable opponent. So the first "if" underlying our argument for the need for COMSEC (Communications Security) is more than a postulate—a deliberate, large, competent force has been identified whose mission is the exploitation of U.S. communications through their interception and analysis.

It is important to understand at the outset why the Soviet Union (as well as all other major countries) is willing to make an investment of this kind. Because, of course, they find it worthwhile. Sometimes, in the security business, you feel like a jackass having run around clutching defense secrets to your bosom only to find a detailed expose in *Missiles and Rockets* or the *Washington Post* or find it to be the subject of open conversations at a cocktail party or a coffee bar. There are, in fact, so many things that we cannot hide in an open society—at least in peace time—that you will sometimes encounter quite serious and thoughtful skepticism on the value or practicability of trying to hide anything . . . particularly if the techniques you apply to hide information—like cryptography—entail money, loss of time, and constraints on action.

What then, is unique about communications intelligence? What does it provide that our mountains of literature and news do not similarly reveal? How can it match the output of a bevy of professional spies or in-place defectors buying or stealing actual documents, blueprints, plans? ("In-place defector"—a guy with a *bona fide* job in some place like the Department of Defense, the Department of State, this Agency, or in the contractual world who feeds intelligence to a foreign power.) It turns out that there *is* something special about communications intelligence, and it provides the justification for our own large expenditures as well as those of other countries: in a nutshell, its special value lies in the fact that this kind of intelligence is generally accurate, reliable, *authentic*, continuous, and most important of all, *timely*. The more deeply you become familiar with classified governmental operations, the more aware you will become of the superficiality and inaccuracy that is liable to characterize speculative journalism. After all, if we've done our job, we have reduced them to speculation—to the seizing of and elaboration on rumors, and to drawing conclusions based on very few hard facts. This is by no means intended as an indictment of the fourth estate—it is merely illustrative of why Soviet intelligence would rather have the contents of a message signed by a government official on a given subject or activity than a controlled news release or journalistic guess on the same subject. Similarly, the outputs of agents are liable to be fragmentary, sporadic, and *slow*; and there are risks entailed in the transmission of intelligence so acquired. [Conventional SIGINT (Signals Intelligence) activity, of course, entails no risk whatever.]

Let me track back again: I have said that there is a large and profitable intercept activity directed against us. This does not mean, however, that the Soviets or anybody else can intercept *all* our communications . . . that is, all of them at once; nor does it necessarily follow that all of them are *worth* intercepting. (The Army has a teletypewriter link to Arlington Cemetery through which they coordinate funeral arrangements and the like. Clearly a very low priority in our master plans for securing communications.) It does mean that this hostile SIGINT activity has to be selective, pick the communications entities carrying intelligence of most value or—and it's not necessarily the same thing—pick the targets most swiftly exploitable. Conversely, we in the COMSEC business are faced with the problem not simply of securing communications, but with the much more difficult problem of deciding which communications to secure, in what time frame, and with what degree of security. Our COMSEC resources are far from infinite; not only are there constraints on the money, people, and equipment we can apply but also—as you will see later on—there are some important limitations on our technology. We don't have that *secure* two-way wrist radio, for example.

In talking of our objectives, we can postulate an *ideal*—total security for all official U.S. Government communications; but given the limitations I have mentioned, our more realistic objectives are to develop and apply our COMSEC resources in such a way as to assure that we provide for our customers a *net advantage vis-a-vis* their opposite numbers. This means that we have to devise systems for particular applications that the opposition will find not necessarily *unbreakable* but too costly to attack because the attack will consume too much of his resources and *too much time*. Here, we have enormous variation—most of our big, modern electronic cryptosystems are designed to resist a full scale "maximum effort" analysis for many, many years; we are willing to invest a big expensive hunk of complicated hardware to assure such resistance when the underlying communications are of high intelligence value. At the other end of the spectrum we may be willing to supply a mere slip of paper designed only to provide security to a tactical communication for a few minutes or hours because the communication has no value beyond that time . . . an artillery spotter names a target; once the shell lands, hopefully on the coordinates specified, he couldn't care less about the resistance to cryptanalysis of the coded transmission he used to call for that strike.

Now, if the opposition brought to bear the full weight of their analytic resources they may be able to solve that code, predict that target, and warn the troops in question. But can they afford it? Collectively, the National Security Agency attempts to provide the commander with intelligence about the opposition (through SIGINT) while protecting his own communications against comparable exploitation—and thus provide the net advantage I spoke of. I'll state our practical objectives in COMSEC once more: not absolute security for all communications because this is too expensive and in some instances, may result in a net disadvantage; but sufficient security for each type of communications to make its exploitation uneconomical to the opposition and to make the recovery of intelligence cost more than its worth to him. Don't forget for a moment that some TOP SECRET messages may have close to infinite worth, though; and for these, we provide systems with resistance that you can talk of in terms of centuries of time and galaxies of energy to effect solution.

The reason I have spent this time on these general notions is the hope of providing you a perspective on the nature of the business we're in and some insights on why we make the kinds of choices we do among the many systems and techniques I'll be talking to you about during the rest of the week. I happened to start out in this business as a cryptanalyst and a designer of specialized manual systems not long after World War II. It seemed to me in those days that the job was a simplistic one—purely a matter of examining existing or proposed systems and, if you found anything wrong, fix it or throw the blighter out—period. In this enlightened spirit, I devised many a gloriously impractical system and was confused and dismayed when these magnificent products were sometimes rejected in favor of some clearly inferior—that is, *less secure* system merely because the alternative was simpler, or faster, or cheaper; or merely because it would *work*.

Those of you who are cryptanalysts will find yourselves in an environment that is necessarily cautious, conservative, and with security *per se* a truly paramount consideration. This, I assert, is *healthy* because you, a mere handful, are tasked with outthinking an opposing analytic force of rhaps 100 times your number who are just as dedicated to finding flaws in these systems as you

must be to assuring none slipped by. But do not lose sight of the real world where your ultimate product must be used, and beware of security features so intricate, elaborate, complex, difficult, and expensive that our customers throw up their hands and keep on communicating in the clear—you have to judge not only the abstract probabilities of success of a given attack, but the likelihood that the opposition will be willing to commit his finite resources to it.

I hope you non-cryptanalysts smiling in our midst will recognize that we're playing with a two-edged sword—you are or ought to be in an environment where there is an enthusiasm for introducing to the field as many cryptosystems as possible at the least cost and with the fewest security constraints inhibiting their universal application. But don't kid yourselves: against the allegation that the COMSEC people of the National Security Agency—we're the villains—are quote pricing security out of the market unquote—is the fact that there is this monolithic opposing force that we can best delight by introducing systems which are not quite or not nearly as good as we think they are.

From this, we can conclude that, to carry out our job we have to do two things: first we have to provide systems which are cryptographically sound; and second, we have to insure that these systems can and will be used for the purpose intended.

If we fail in the first instance, we will have failed those customers who rely on our security judgments and put them in a disadvantageous position with respect to their opposition. But if we fail to get the systems used—no matter *how* secure they are—we are protecting nothing but our professional reputation.

Now that the general remarks about why we're in this business and what our objectives are are out of the way, we can turn to the meat of this course—my purpose, as much as anything, is to expose you to some concepts and teach you a new language, the vocabulary of the peculiar business you're in. To this end I will try to fix in your minds a number of rather basic notions or approaches that are applied in cryptography as well as a number of specific techniques as they have evolved over the past two decades.

There's a fair amount of literature—like the Friedman lectures—which is worth your time and which will trace the art of cryptography or ciphering back to Caesar or therabouts. I'll skip the first couple of millennia and such schemes as shaving a slave's head, writing a message on his shining pate, letting the hair grow back and dispatching him to Thermopylae or where have you. I'll also skip quite modern techniques of *secret writing*—secret inks, microphotography, and open letters with hidden meanings (called "innocent text" systems)—merely because their use is quantitatively negligible in the U.S. COMSEC scheme of things, and this Agency has practically nothing to do with them. What we will be addressing are the basic techniques and systems widely used in the protection of U.S. communications and which we are charged to evaluate, produce, or support.

All of our systems have one obvious objective: to provide a means for converting intelligible information into something unintelligible to an unauthorized recipient. We have discovered very few *basic* ways to do this efficiently. Some of the best ways of doing it have a fatal flaw; that is, that while it may be impossible for the hostile cryptanalyst to recover the underlying message because of the processing given it, neither can the intended recipient recover it because the process used could not be duplicated! On occasion there has been considerable wry amusement and chagrin on the part of some real professionals who have invented sophisticated encryption schemes only to find they were irreversible—with the result that not only the cryptanalyst was frustrated in recovering the plain text, so was the addressee. The inventor of a cryptosystem must not only find a means for rendering information unintelligible, he must use a process which is logical and reproducible at the receiving end. All of you know already that we use things called "keys" which absolutely determine the specific encryption process. It follows from what I have just said that we *always* produce at least two of them, one for the sender, one for the recipient. Through its application, and only through its application, the recipient is able to reverse, unscramble, or otherwise undo the encryption process.

The techniques that we have found useful so far amount to only two: first *substitution* of something meaningless for our meaningful text (our plain language); and second; *transposition*—keeping our original meaningful text, but jumbling the *positions* of our words or letters or digits so they no

longer make sense. This latter technique is so fraught with security difficulties—it's nothing but fancy anagramming—that for all practical purposes you can toss it out of your lexicon of modern U.S. cryptography.

We are left with one very large family of systems in which the basic technique involves the substitution of one value for another. These range from systems whose security stems from a few letters, words, or digits memorized in somebody's head, through a variety of printed materials that permit encryption by use of paper and pencil, to the fancy electronic computer-like gadgets about which you have by now probably heard most. The first category of these systems we're going to talk about is manual systems and the first of these is codes. Professional cryptographers have been talking about codes, using them, attacking them, and solving them for many years. The traditional definition of them is: Code: "A substitution cryptosystem in which the plaintext elements are primarily words, phrases, or sentences, and the code equivalents (called "code groups") typically consist of letters or digits (or both) in otherwise meaningless combinations of identical length."—JUNE 71—*Basic Cryptologic Glossary.*

This definition provides a convenient way for differentiating a "code" from any other substitution system—all the other systems, which we call "ciphers", have a fixed relationship between the cipher value and its underlying meaning—each plaintext letter is always represented by one or two or some other specific number of cipher characters. Incidentally, we use "character" as a generic term to cover numbers or letters or digits or combinations of them. Let's look at a couple of codes:

1. The simplest kind, called a "one-part code", simply lists the plaintext meanings alphabetically (so that you can find them quickly) and some corresponding code groups (usually alphabetized also):

BRIGADE	ABT
COORDINATE(S)	AXQ
DIRECT ARTILLERY FIRE AT_____	CDL
ENGAGE ENEMY AT	GGP
-----	HLD
-----	JMB

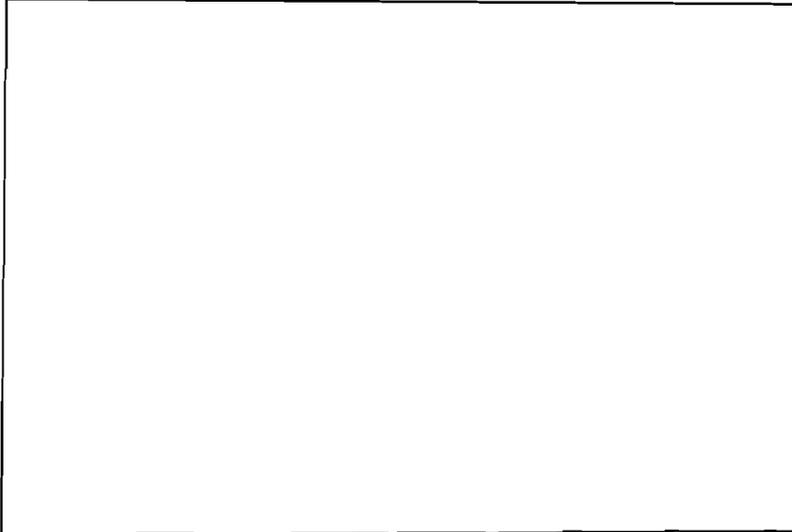
There will usually be some numbers and perhaps an alphabet in such a code so that you can specify time and map coordinates and quantities and the like, and so that you can spell out words, especially place names, that could not be anticipated when the code was printed. Such a code has lots of appeal at very low echelons where only a very few stereotyped words, phrases, or directions are necessary to accomplish the mission. They are popular because they are simple, easy to use, and relatively fast. The security of such systems, however, is very, very low—after a handful of messages have been sent, the analyst can reconstruct the probable exact meanings of most of the code groups. We therefore take a dim view of them, and sanction their use only for very limited applications.

2. The kind of code we do use in very large quantities is more complicated, larger, and more secure. It is called a "two-part code": it is printed in two sections, one for encoding and the other for decoding:

ENCODE	DECODE
BRIGADE CDL	ABT
COORDINATE(S) AXQ	AXQ . . . COORDINATE(S)
DIRECT ARTILLERY FIRE AT_____ JMB	CDL . . . BRIGADE
ENGAGE ENEMY AT GGP	GGP . . . ENGAGE ENEMY AT
----- HLD	HLD
----- ABT	JMB . . . DIRECT ARTILLERY FIRE AT_____

~~SECRET NOFORN~~

The main thing that has been done here is to break up the alphabetical relationship between the plaintext meanings and the sequence of code groups associated with them—that is, the code groups are assigned in a truly random fashion, not in an orderly one. This complicates the cryptanalyst's job; but he can still get into the system rather quickly when the code is used repeatedly. As a result, a number of tricks are used to refine these codes and limit their vulnerability. The first trick is to provide more than one code group to represent the more commonly used words and phrases in the code vocabulary—we call these extra groups "variants" and in the larger codes in use today it is not uncommon to have as many as a half-dozen of these variants assigned to each of the high frequency (i.e., commonly used) plaintext values. Here's an excerpt from a code actually in use today showing some variants:



You probably know that "monoalphabetic substitution systems" were simple systems in which the same plaintext value was always represented by the same cipher or code value—repeats in the plain text would show up as repeated patterns in the cipher text, so lovely words like "RECONNAISSANCE" convert to, say,

RECONN AISSA NCE . . . duck soup! it says here.
SDEGGB XMLLX BED

Well, with an ordinary code, that's exactly the problem. It is essentially a monoalphabetic system with a few variants thrown in, but with most repeated things in the transmitted code showing up as repeated items. This means, where we have to use codes (and later on, I'll show you why we have to in *huge* quantities), we have to do some things more fundamental than throwing in a few stumbling blocks like variants for the cryptanalyst. There are two techniques which are basic to our business and which we apply not only to codes but to almost all our keying materials. These are crucial to the secure management of our systems. These techniques are called *supersession* and *compartmentation*. They provide us a means for limiting the volume of traffic that will be encrypted in any given key or code; the effect of this limitation is to reduce the likelihood of successful cryptanalysis or of *physical loss* of that material; and further to reduce the scope of any loss that does occur.

SUPERSESSION is simply the replacement of a code or other keying material from time to time with new material. Most keys and codes are replaced each 24 hours; a few codes are replaced as frequently as each six hours; a few others remain effective for three days or more. We have these differing supersession rates because of the different ways in which the materials may be used. Holders of some systems may send only one message a day—everything else being equal, his system will have much greater resistance to cryptanalysis than that of a heavy volume user and his system will not

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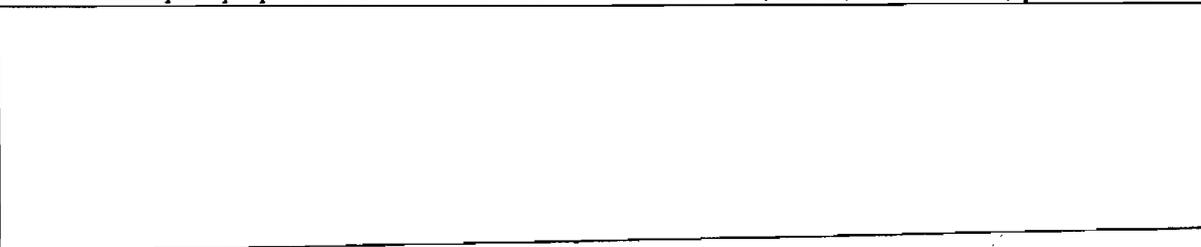
ORIGINAL 13

quire replacement as often. The regular replacement rate of material each six hours or 24 hours or three days or what have you is called the "normal supersession rate" of the material in question. "Emergency supersession" is the term used when material is replaced prematurely because it may have been physically lost.

Once again, the purpose of periodic supersession of keying material and codes is to limit the amount of traffic encrypted in any one system and thus to reduce the likelihood of successful cryptanalysis or of physical loss; and to limit the effect of loss when it does occur. The resistance to cryptanalysis is effected by reducing the amount of material the cryptanalyst has to work on and by reducing the *time* he has available to him to get at *current* traffic.

COMPARTMENTATION is another means for achieving control over the amount of classified information entrusted to a specific cryptosystem. Rather than being geared to time, as in the case of supersession, it is geared to communications entities, with only those units that have to intercommunicate holding copies of any particular key or code. These communications entities in turn tend to be grouped by geography, service, and particular operational mission or specialty. Thus, the Army artillery unit based in the Pacific area would not be issued the same code being used by a similar unit in Europe—the vocabularies and procedures might be identical, but each would have unique code values so that loss of a code in the Pacific area would have no effect on the security of messages being sent in the Seventh Army in Europe, and vice versa. Of course some systems, particularly some machine systems, are designed specifically for intercommunication between two and only two holders—between point A and point B, and that's all. In such a case, the question of "compartmentation" doesn't really arise—the system is inherently limited to a compartment or "net" of two. But this is rarely the case with ordinary codes; and some of them must have a truly worldwide distribution. So our use of compartmentation is much more flexible and less arbitrary than our use of supersession; occasionally we will set some absolute upper limit on the number of holders permissible in a given system because cryptanalysis shows that when that number is exceeded, the time to break the system is worth the hostile effort; but in general, it is the minimum needs, for intercommunication that govern the size (or, as we call it, the copy count) of a particular key list or code.

Now I have said that compartmentation and supersession are techniques basic to our whole business across the spectrum of systems we use. Their effect is to split our security systems into literally thousands of separate, frequently changing, *independent* entities. This means, of course, that the notion of "breaking *the* U.S. code" is sheer nonsense—the only event that could approach such catastrophic proportions for U.S. COMSEC would be covert (that is, undiscovered) penetration



The reason I've injected these concepts of compartmentation and supersession into the middle of this discussion of codes, although they have little to do with the structure of codes themselves, is that, despite our variants, and tricks to limit traffic volume, and controls over operational procedures, *codes as a class remain by far the weakest systems we use*; and these techniques of splitting them into separate entities and throwing them out as often as possible are essential to obtaining even the limited short-term security for which most of them are intended.

Having said, in effect, that codes as a class are not much good, let me point out that there are specialized paper and pencil systems which more or less conform to the definition of "code" but which are highly secure. Before I do this, let me return to the definition of code we started from, and suggest an alternative definition which more nearly pin-points how they *really* differ from other techniques of encryption. You remember we said the thing that makes a code unique is the fact that

the code values can represent underlying values of different lengths—to recognize this is important to the cryptanalyst and that is the feature that stands out for him. But there is something even more basic and unique to a code: that is the fact that each code group—that QXB or what-have-you—stands for something that has *intrinsic meaning*, i.e., each underlying element of plain text is cognitive; it is usually a word or a phrase or a whole sentence. In every other system of encryption, this is not so; the individual cipher value stands only for an arbitrary symbol, meaningless in itself—like some binary digit or a letter of the alphabet. So I find, when examining a code, that QXB means “FIRE A GUN,” or “REGROUP AT THE CROSSROADS,” or “QUARTERBACK SNEAK,” or what-have-you. In a *cipher* system, QXB might mean “X” or “L” or “001” or something else meaningless in itself. I’ve touched on this partly because the new cryptologic glossary has defined a code in terms of the meaning—or meaningfulness—of the underlying textual elements. I wouldn’t push the distinction too far—it gets hazy when you are *spelling* with a code; get around it by admitting that, during the spelling process, you are in fact retaining a one-to-one relationship between the size of the underlying values and those being substituted for them—you are, for the moment, “enciphering” in the code.

The “One-Time” Concept.—I have said that at the heart of a code’s insecurity is the fact that it is essentially a monoalphabetic process where the same code group always stands for the same underlying plaintext value. The way to lick this, of course, is to devise a system where each code value is used once and only once. Repeats don’t show up because there aren’t any, and we have effectively robbed the cryptanalyst of his “entering wedge” into the cryptosystem. Let’s look at several such systems:

ARTILLERY: ABD	BRIGADE: MJX
QVM	ZIY
CXD	RDF
EVL	QLW
QSI	

.....
etc.

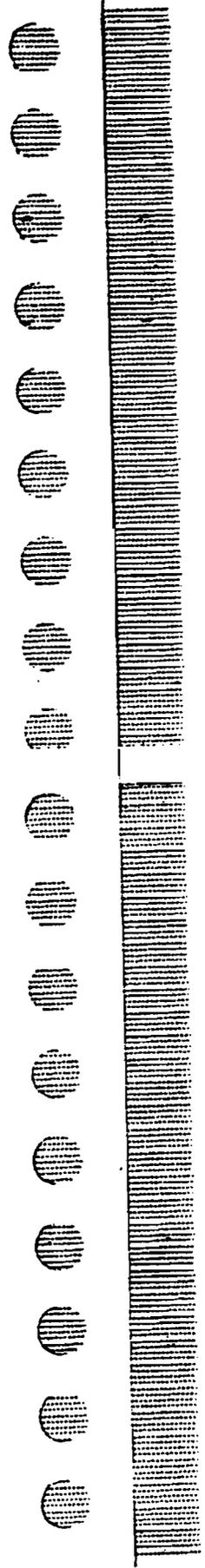
Well! This thing looks like nothing more than one of those ordinary codes we talked about, but with a set of variants assigned to each item of the vocabulary. Right. But suppose I make a rule that each time you use a variant, you check it off or cross it out, and must not use it again? By this simple expedient, I have given you a *one-time system*—a system which is for all practical purposes immune to cryptanalysis, perfectly secure? Sounds nice, and you might wonder why we have not adopted it for universal use. Well, let’s look at some of the constraints inherent in this simple procedure:

Right now, if I have a very large vocabulary in a standard two-part code, it may run up to 32 pages or more. (The largest is 64 pages). If I have to insert say a half-dozen code values for every plaintext entry, my code book gets to be about 200 pages long, rather awkward to jam in the most voluminous of fatigue pockets, and a most difficult thing to thumb through—jumping back and forth, mind you—as you do your encoding or decoding process. So, limitation number one: we have to confine the technique to codes of quite small vocabularies.

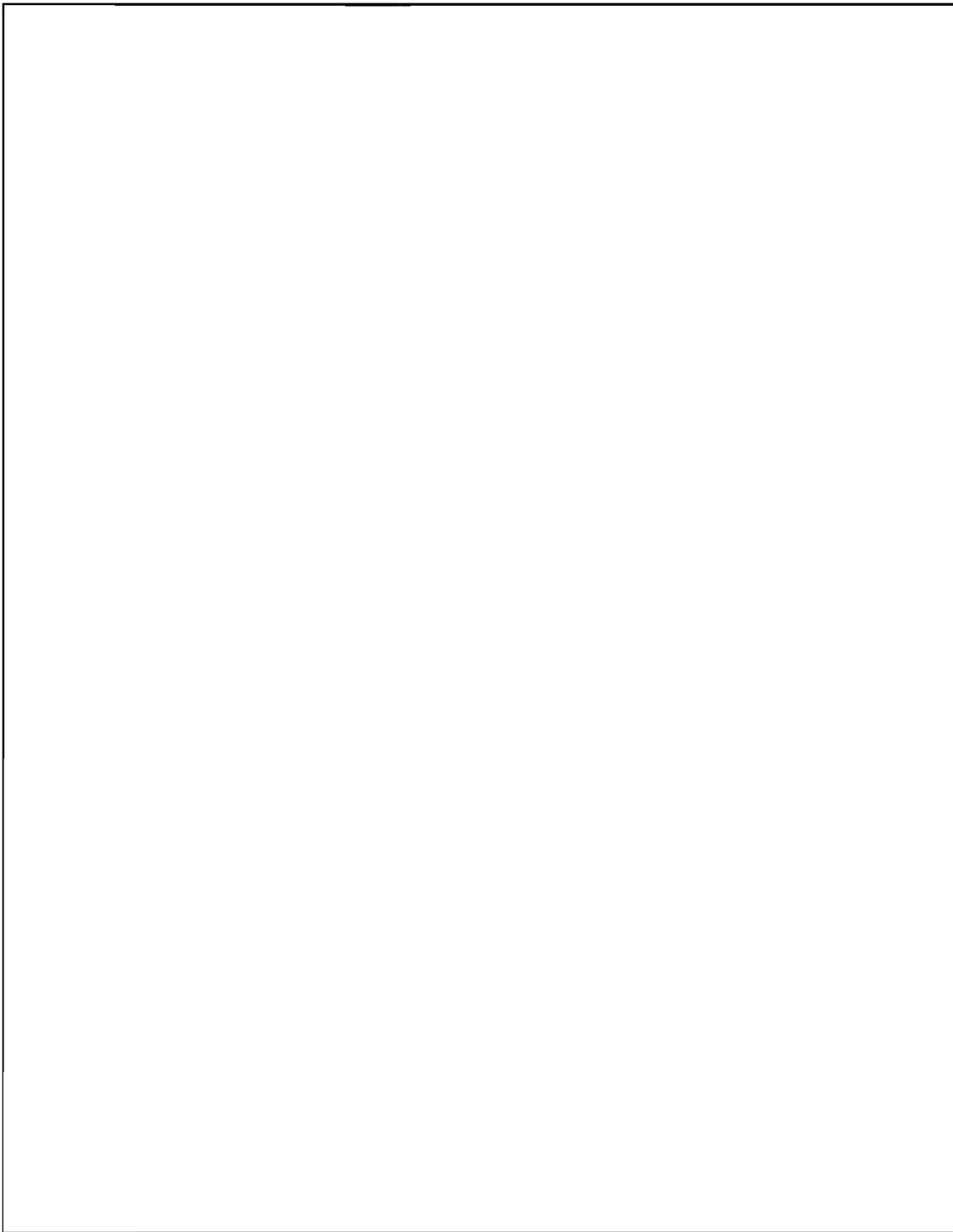
Suppose my “compartment” (my net size) is 20 holders for this code. How does any given user know which values other holders in the net have used? He doesn’t. He doesn’t unless everybody listens to everybody else all the time, and that doesn’t often happen. And this is really the killing limitation on most one-time systems of this kind. You wind up saying only *one* holder can send messages in the code, and all other copies are labelled “RECEIVE ONLY”. We call this method of communications “Broadcast” and it has rather narrow applications. Alternatively, we can provide each of our 20 holders with a SEND code and 19 RECEIVE codes—but try to visualize some guy in an operational environment scrambling through 19 books to find the right one for a given incoming message; and look at the logistics to support such a system: it turns out that the number of books you need is the *square* of the number of holders you want to serve in this way—400 books for a 20-

holder net—10,000 for 100 holders! So limitation number two: the size of a net that you can practically operate in this way is very small: preferably just two stations.

Let's turn now to another kind of one-time code; one that we call a "pro forma" system. "Pro forma" means that the basic framework, form or format of every message text is identical or nearly so; the same kind of information, message after message, is to be presented in the same order, and only specific values, *like numbers*, change with each message.



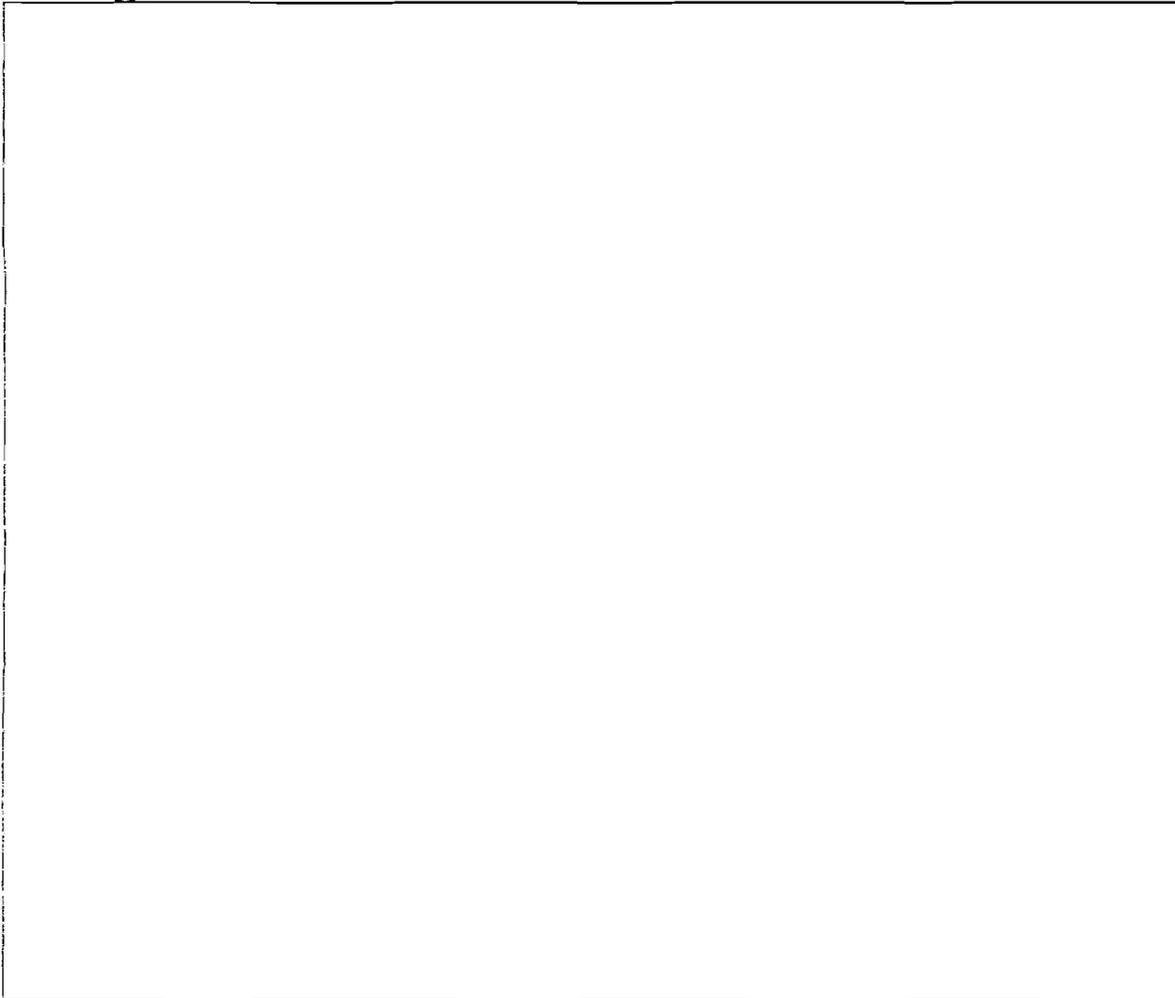
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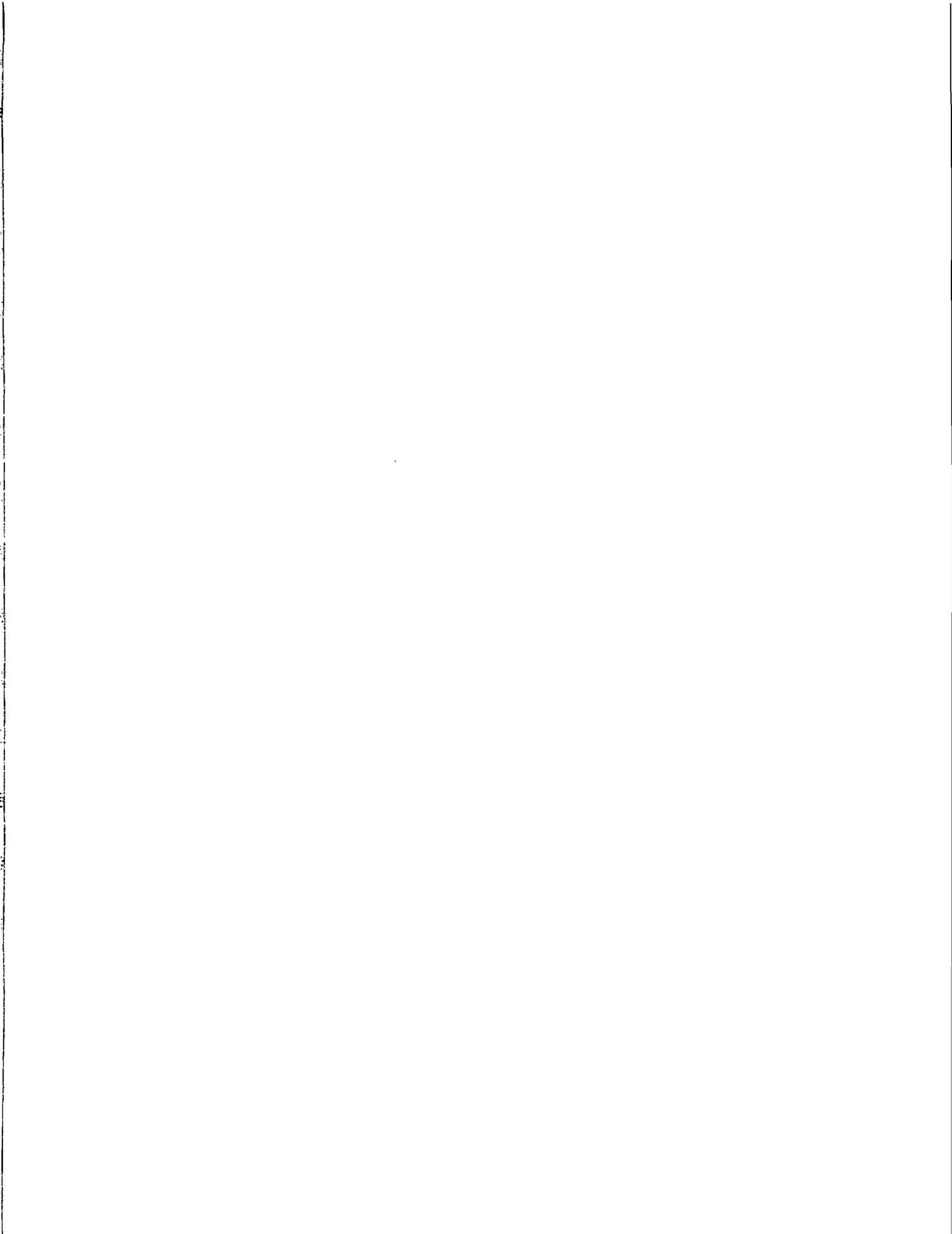
Now we're beginning to get something more manageable: We still have the constraint of needing a small net size or, alternatively, a larger net but with only one or a few senders of information. But it's a dandy where the form of the messages themselves permit this terrible inflexibility. We use a few of them, but machines are the things we're moving towards to meet most of the requirements of this type.



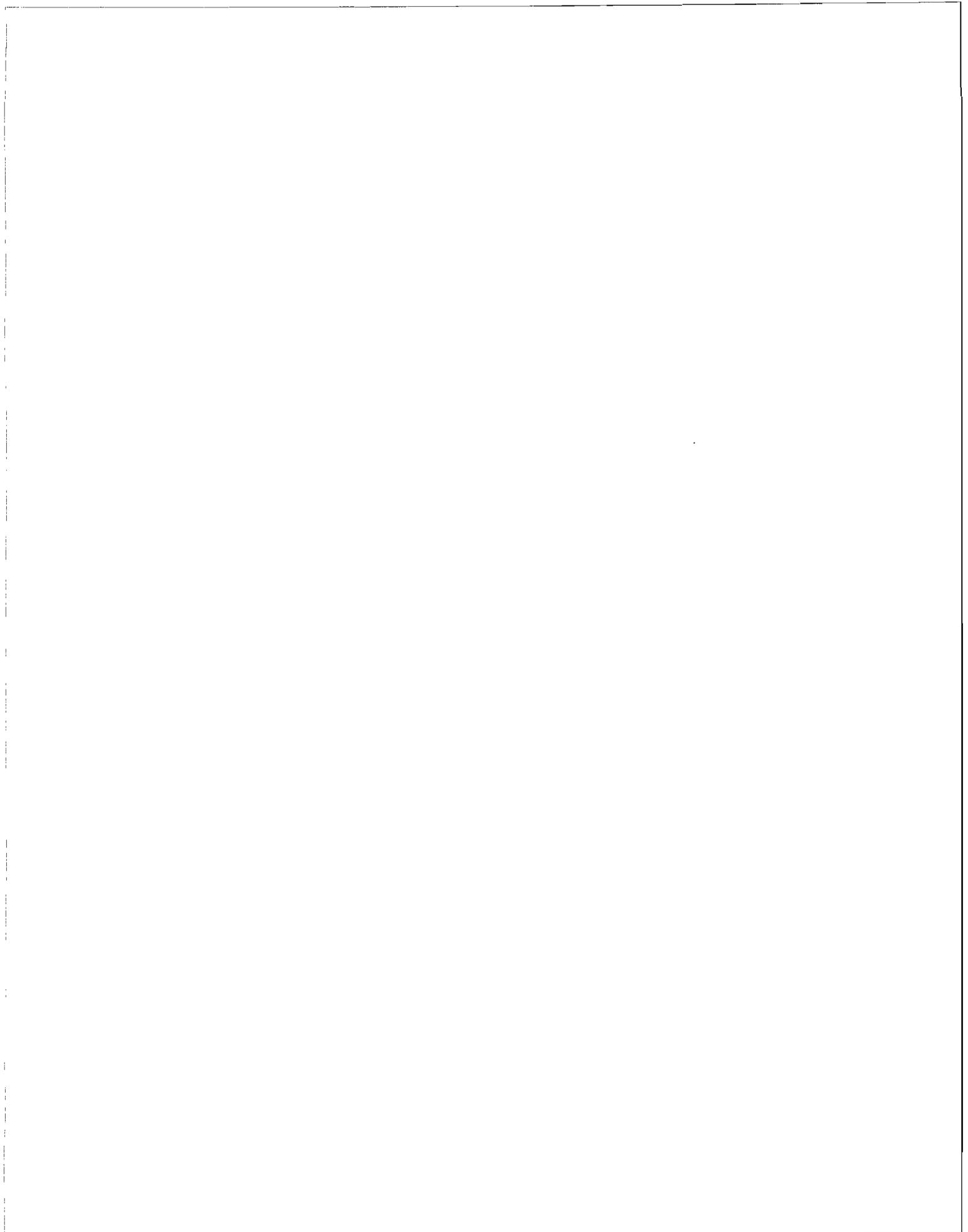
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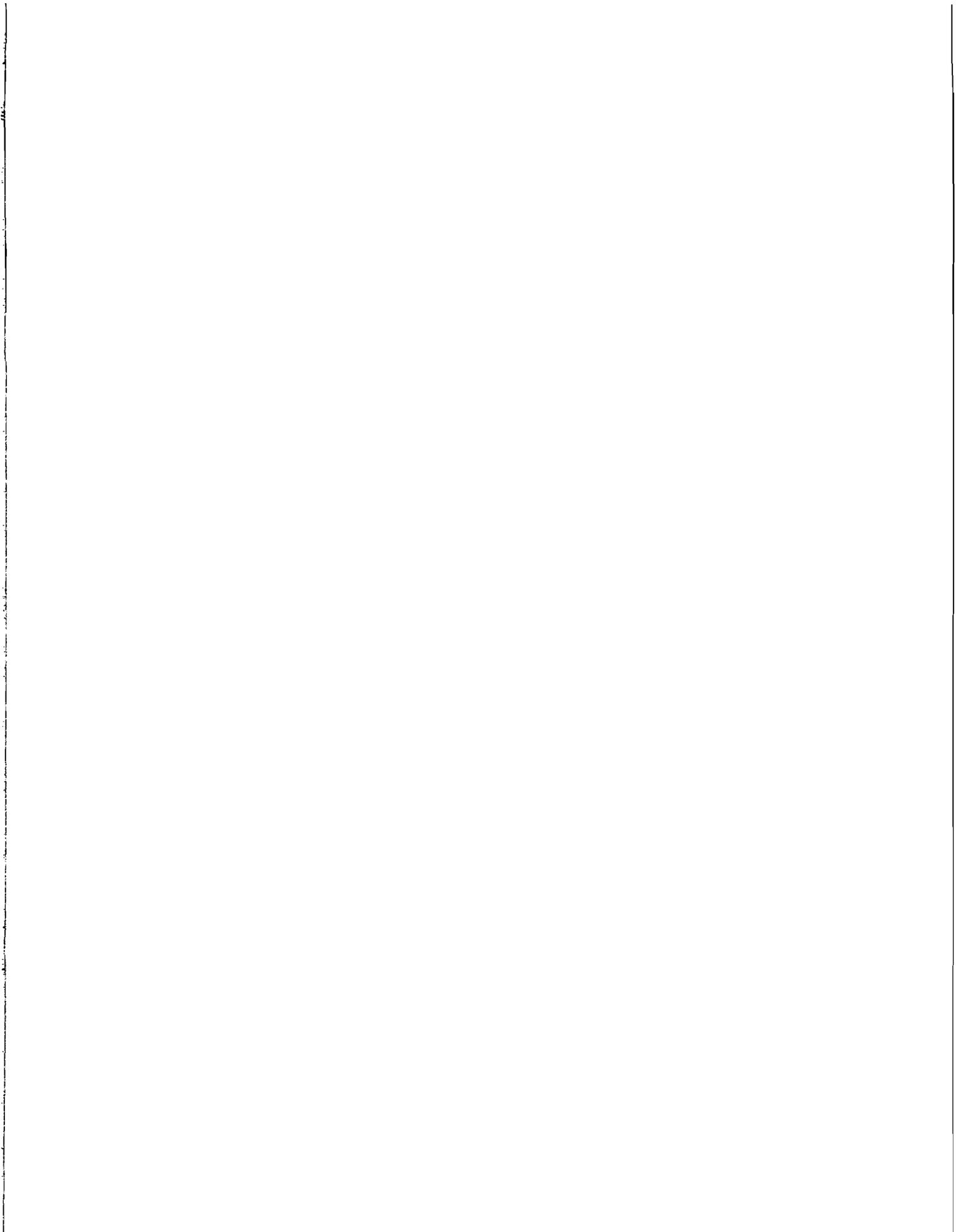
In comparing this one-time system and the last one I showed you, I think you'll begin to see a number of characteristics emerge for these specialized codes: first off, they are relatively secure: I say relatively, because there is more to communications security than resistance to cryptanalysis—and while these systems meet that first test—cryptanalysis—admirably, from the *transmission security* point of view, they're pretty bad; but we'll be talking about that on another day. Secondly: they are inflexible, rigidly confined with respect to the variety of intelligence they can convey. Thirdly: they are built for *speed*; they are by far the fastest means of communicating securely without a machine. Finally, they are extremely specialized, narrow in their application, and limited in the size of communications network they can serve efficiently. Being specialized, by the way, and *tailored* to particular needs, they fly in the face of efforts to *standardize* our materials—a very necessary movement in a business where we have to make hundreds of codes, distribute them all over the world, replace most of them daily and, as a result, wind up with a total copy count numbering, at the moment, about 5 million each year.

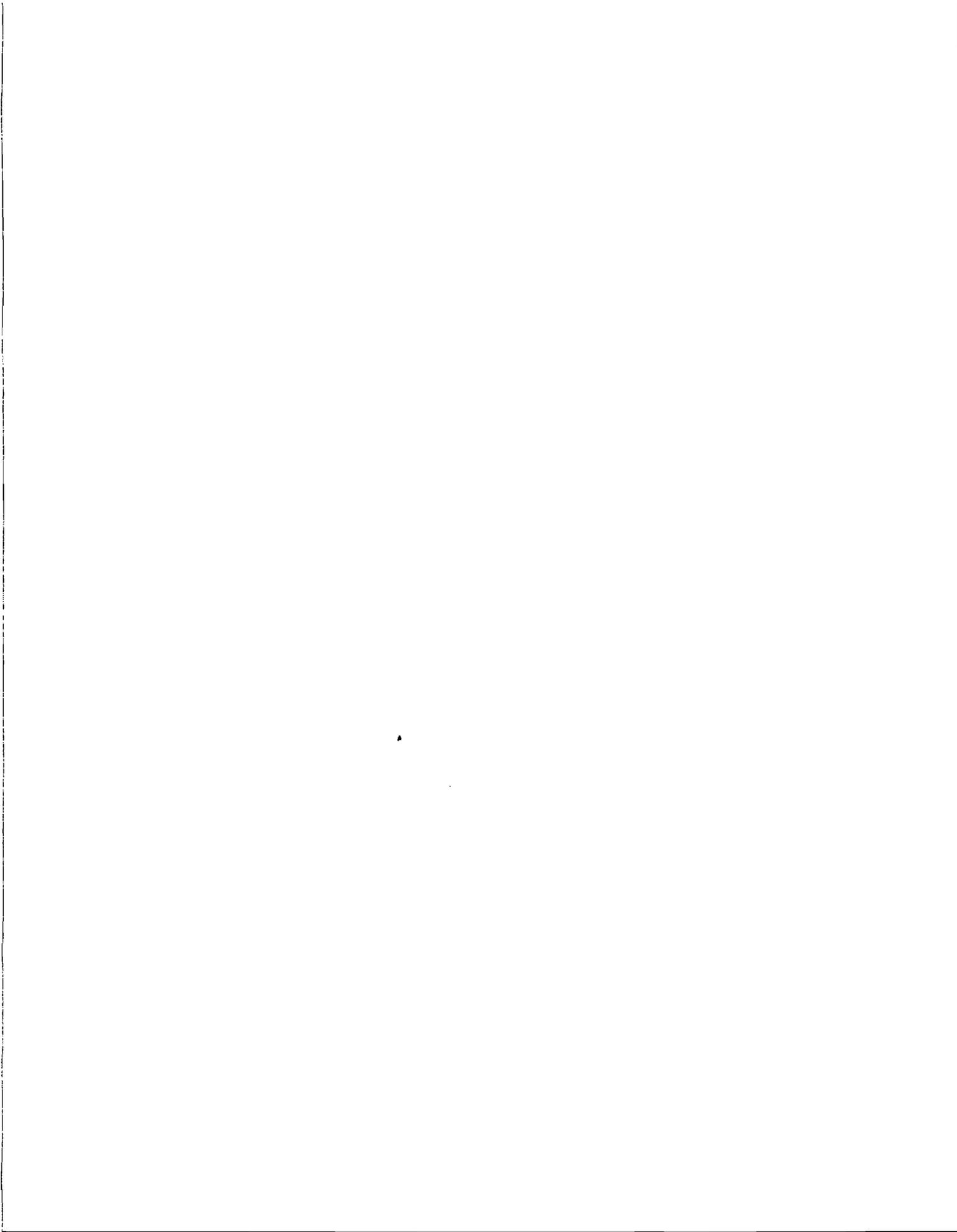
The business of standardizing on the one hand, for the sake of economy, simplicity, and manageability and of uniquely tailoring systems for maximum efficiency in some particular application, is one of the many conflicting or contradictory themes in our business; just as maximum security may conflict with speed or something else.

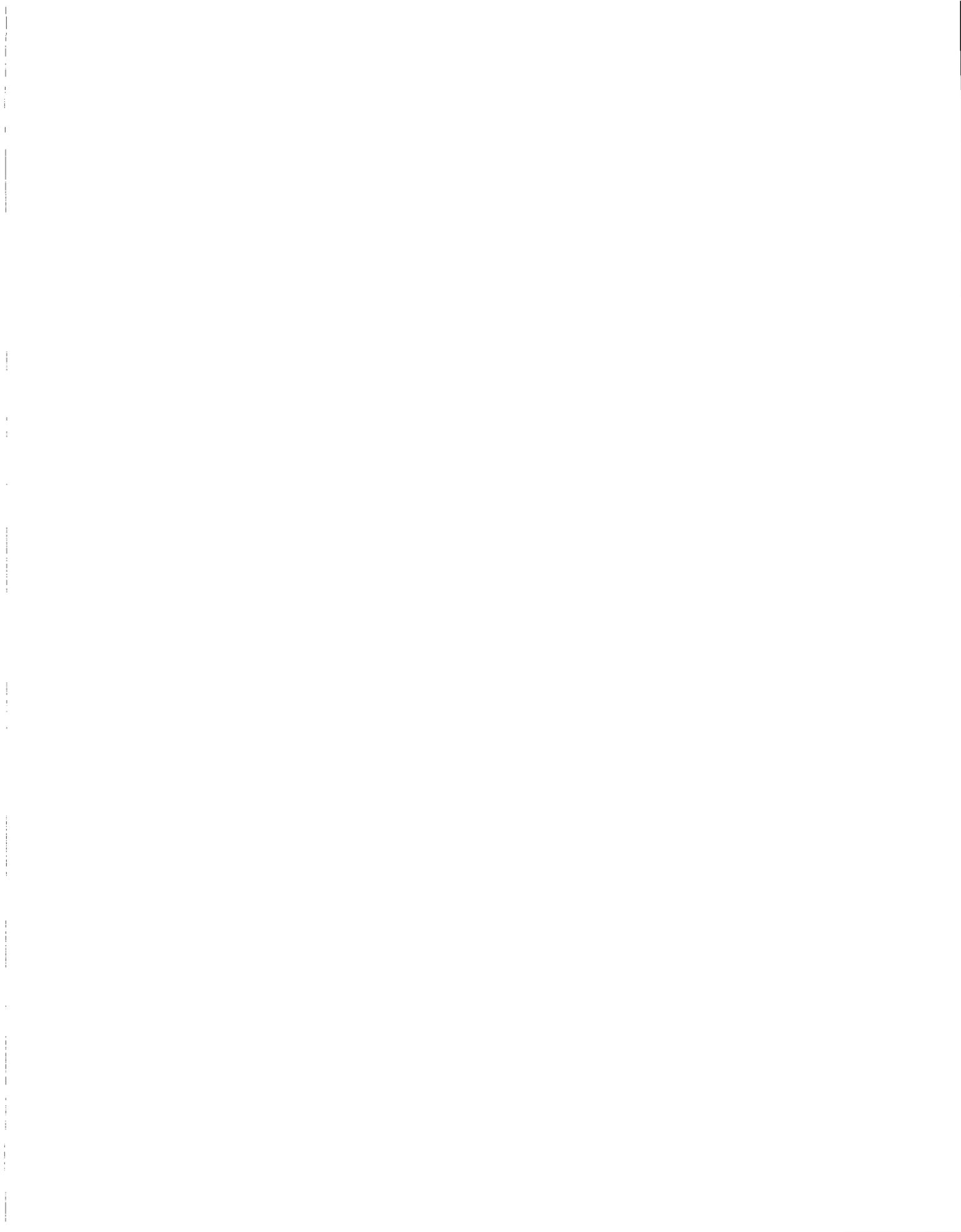




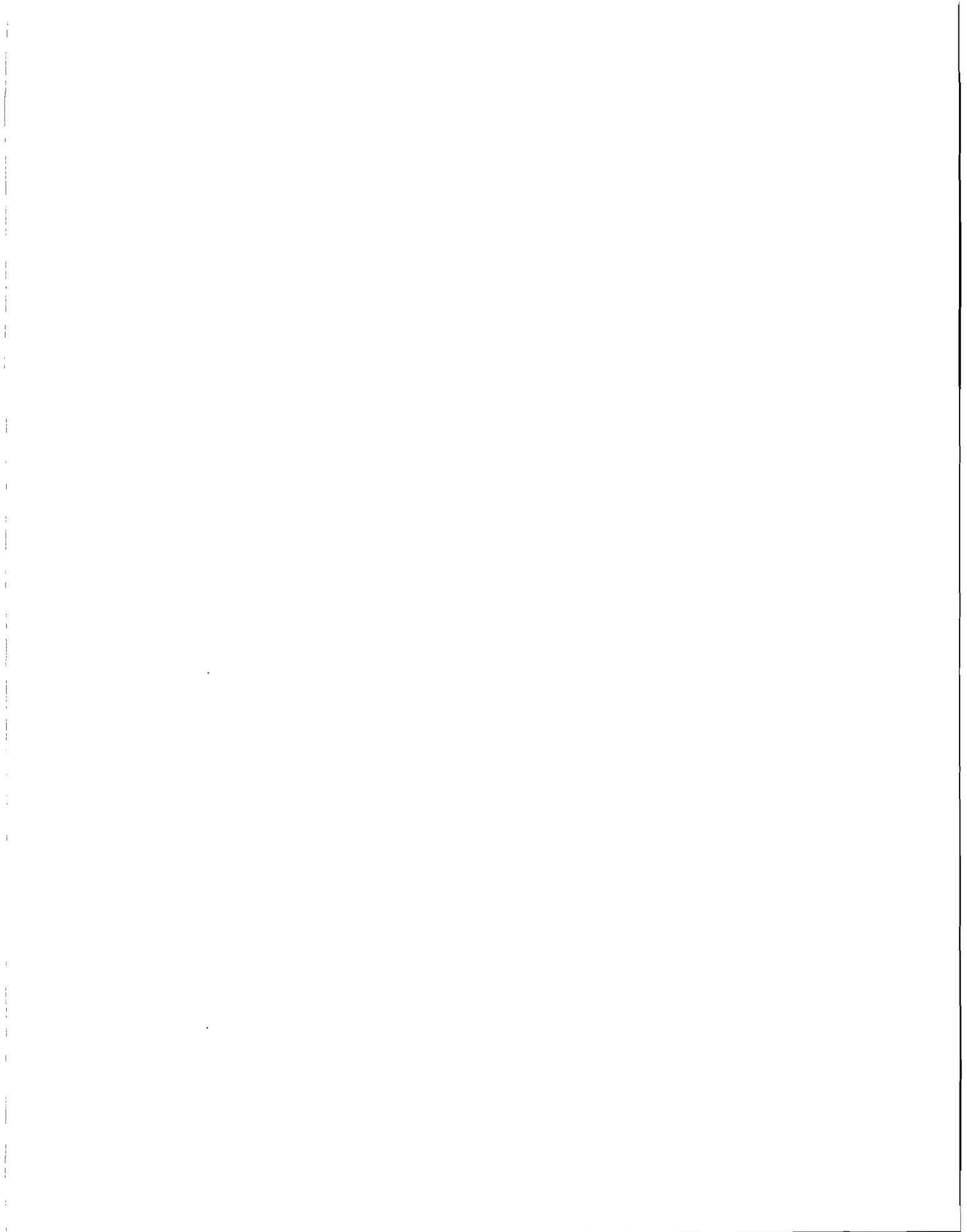


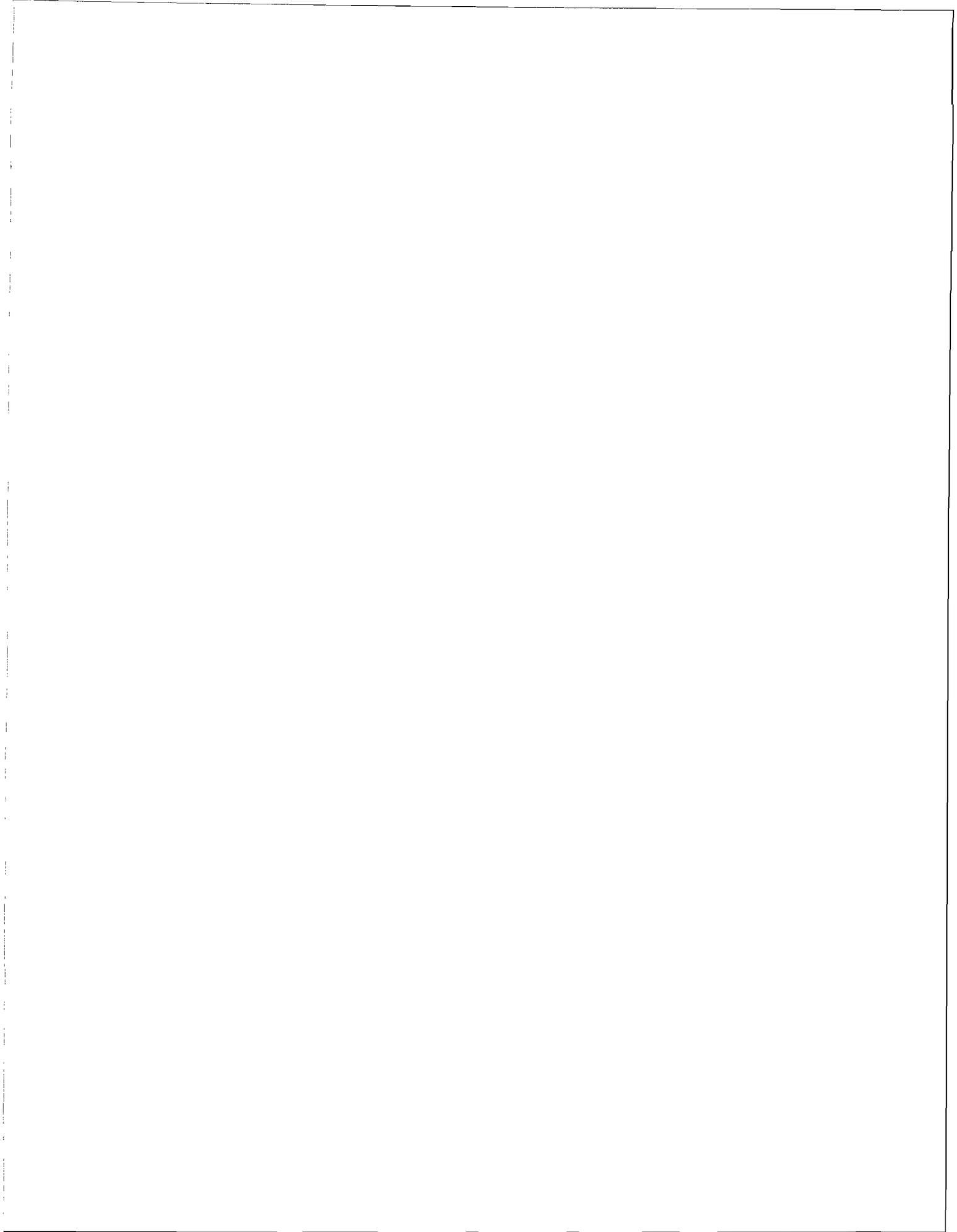




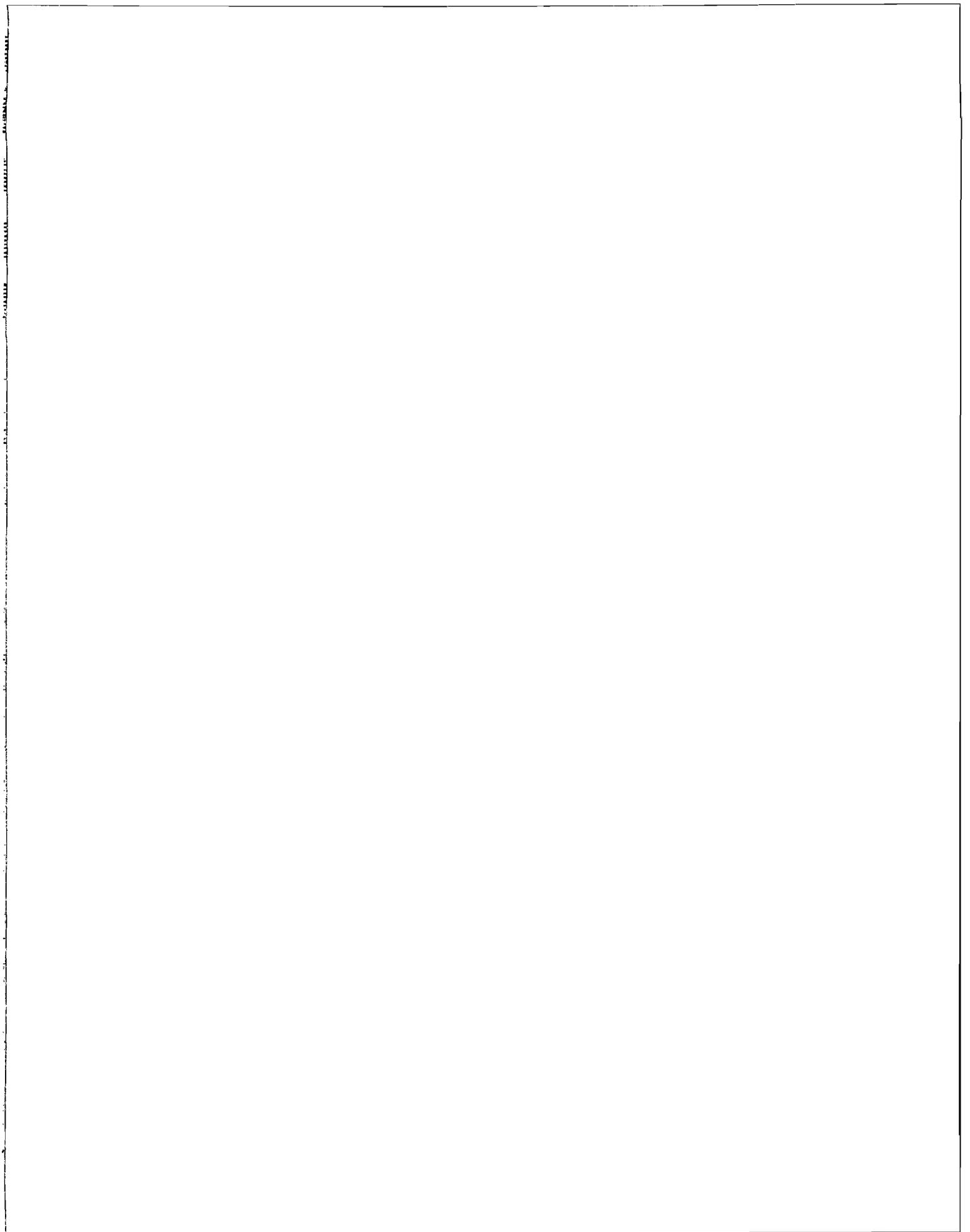


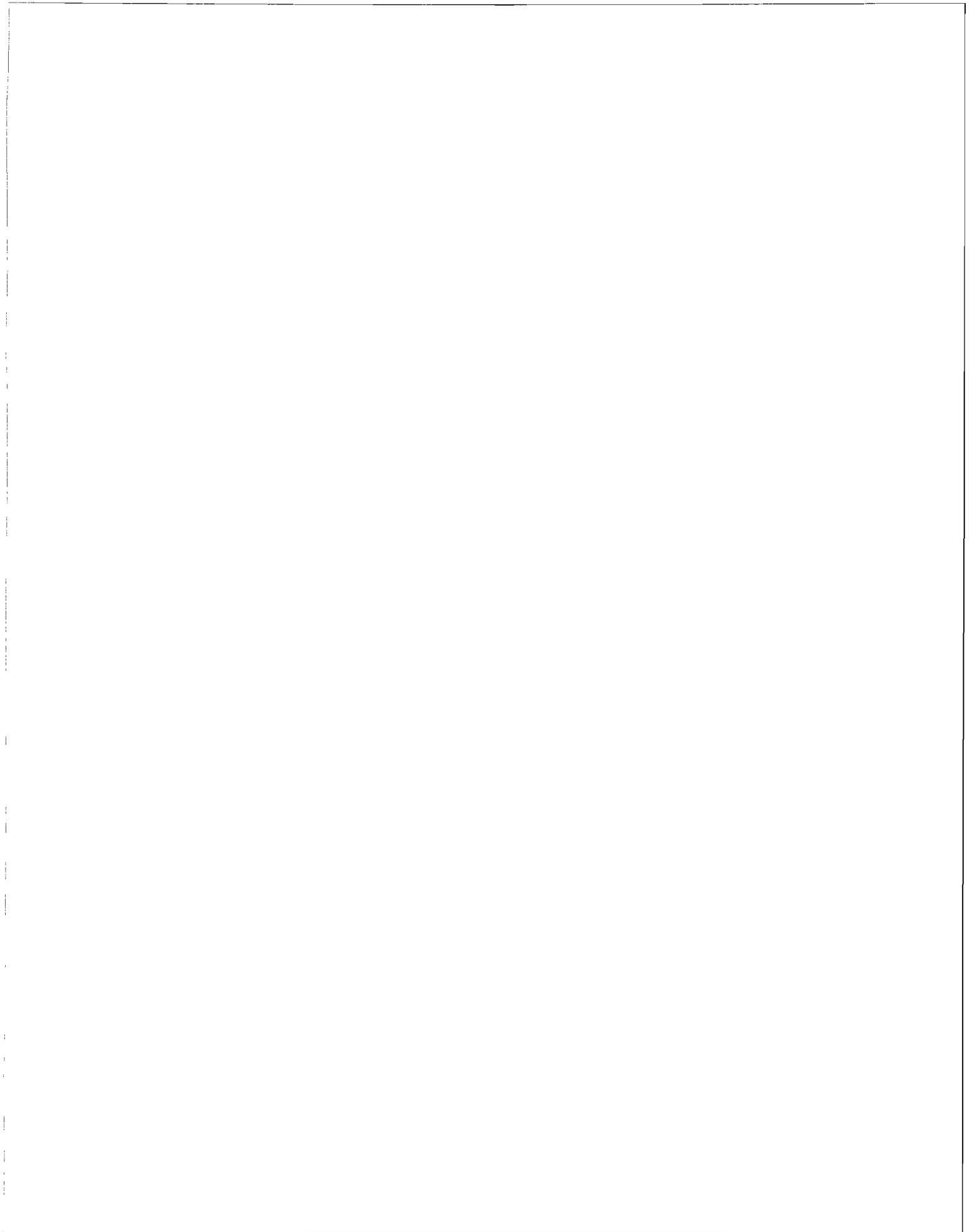


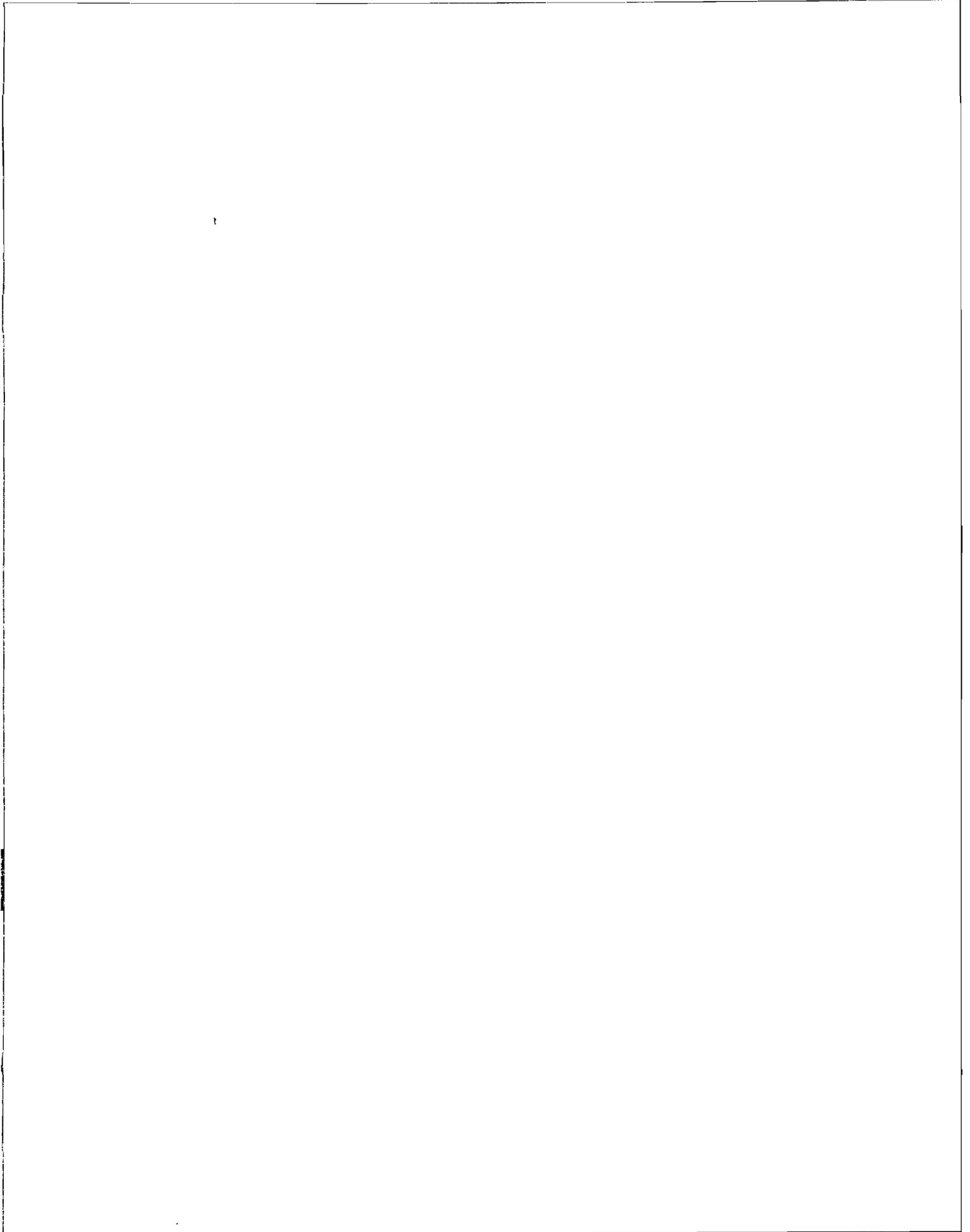


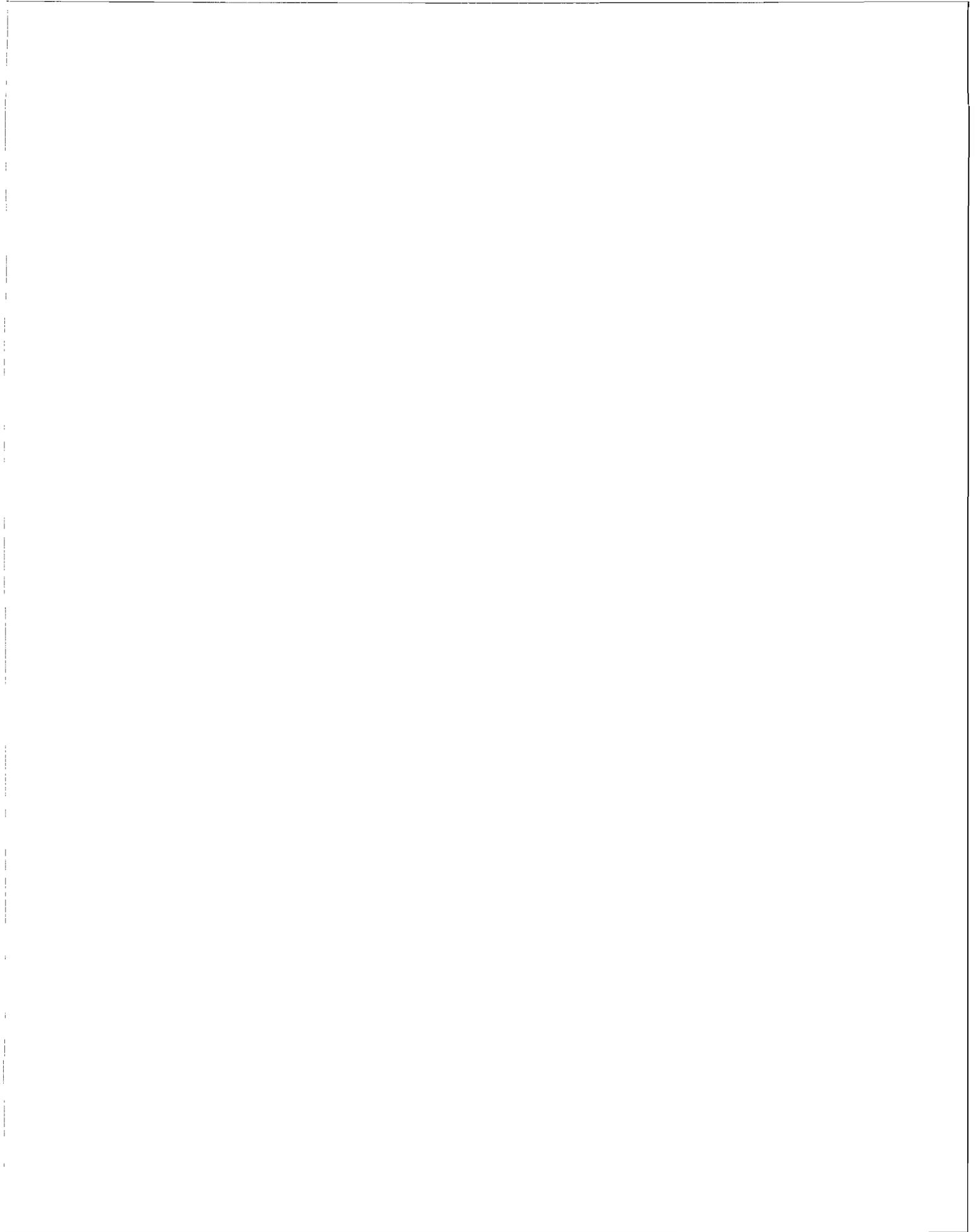


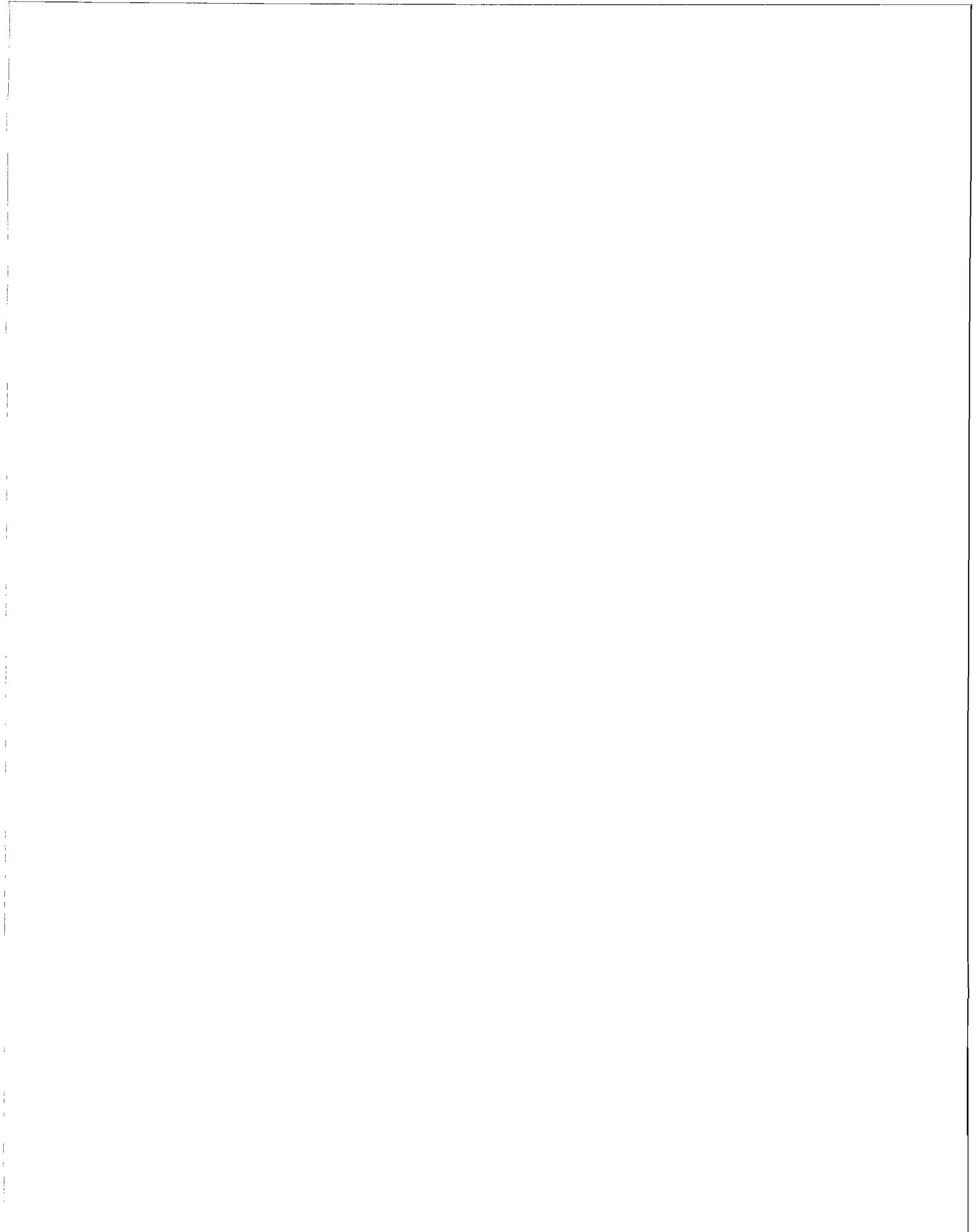


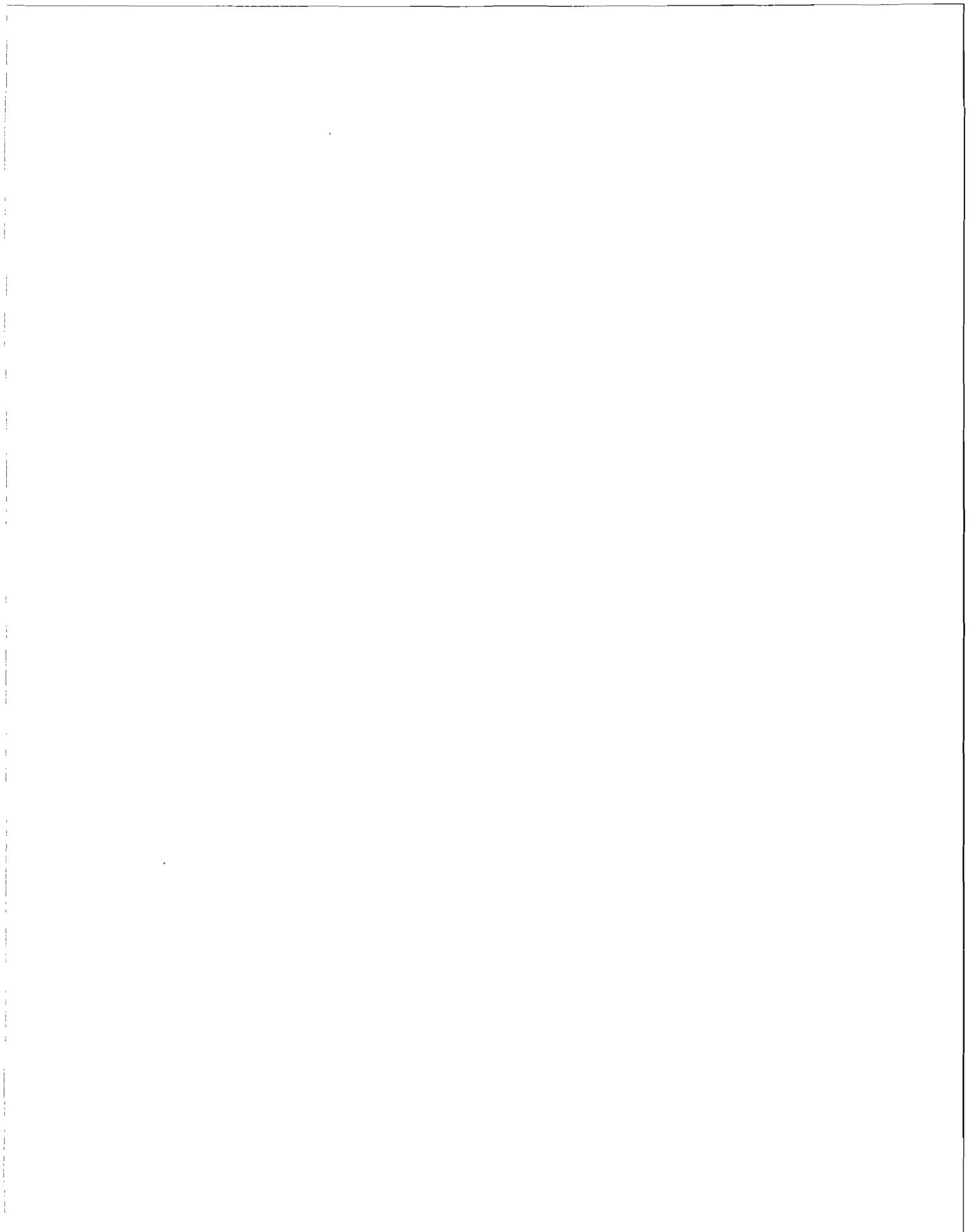


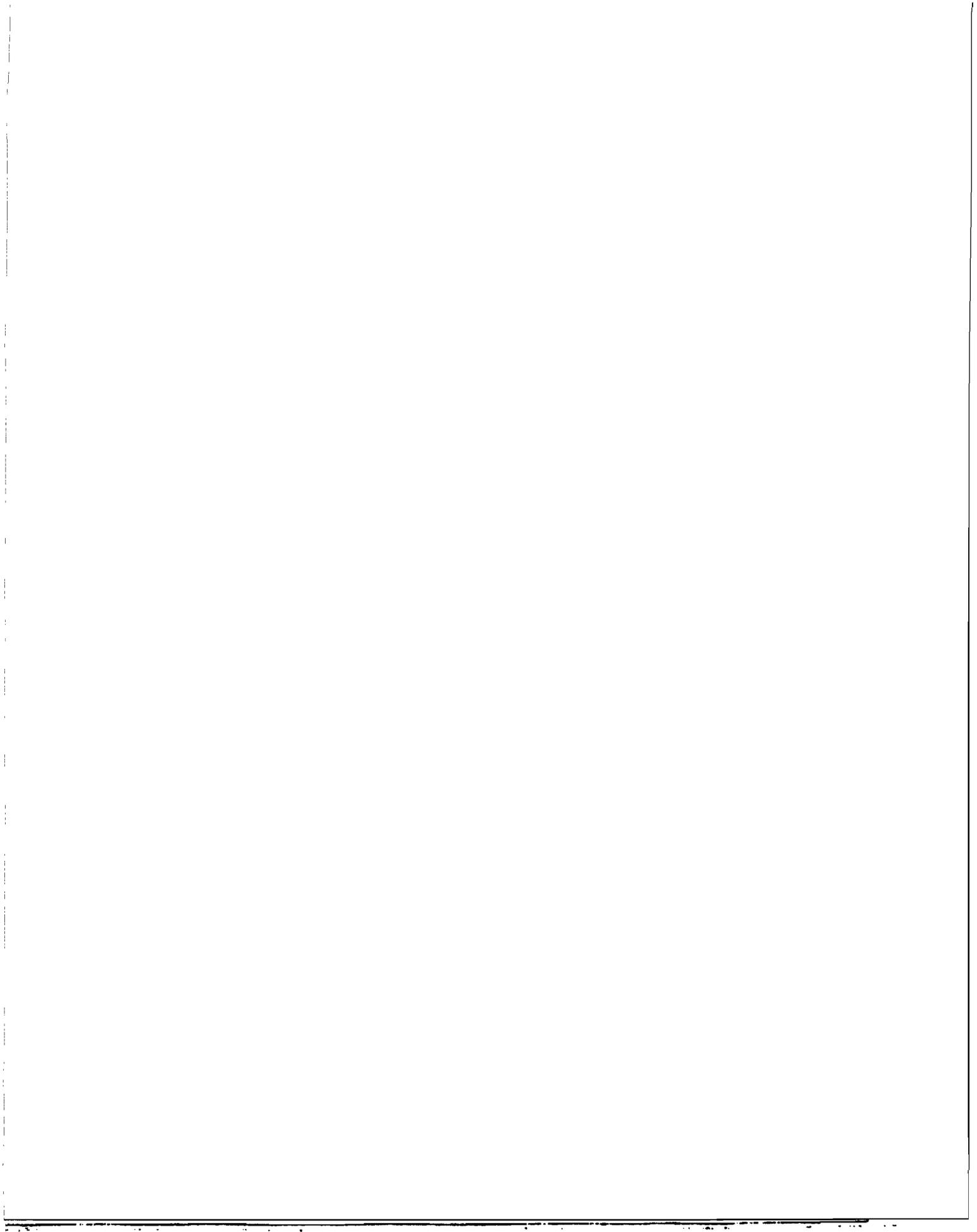


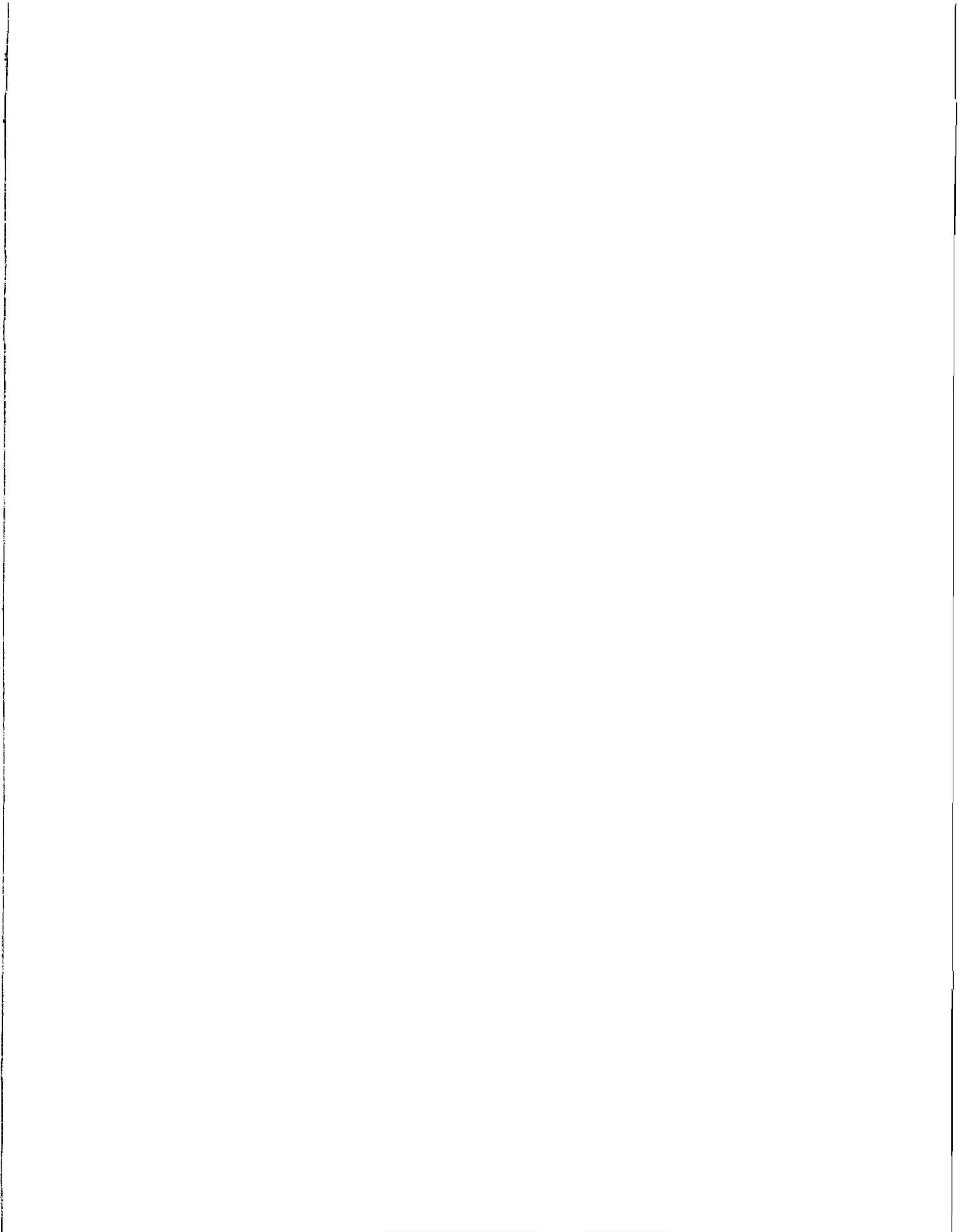


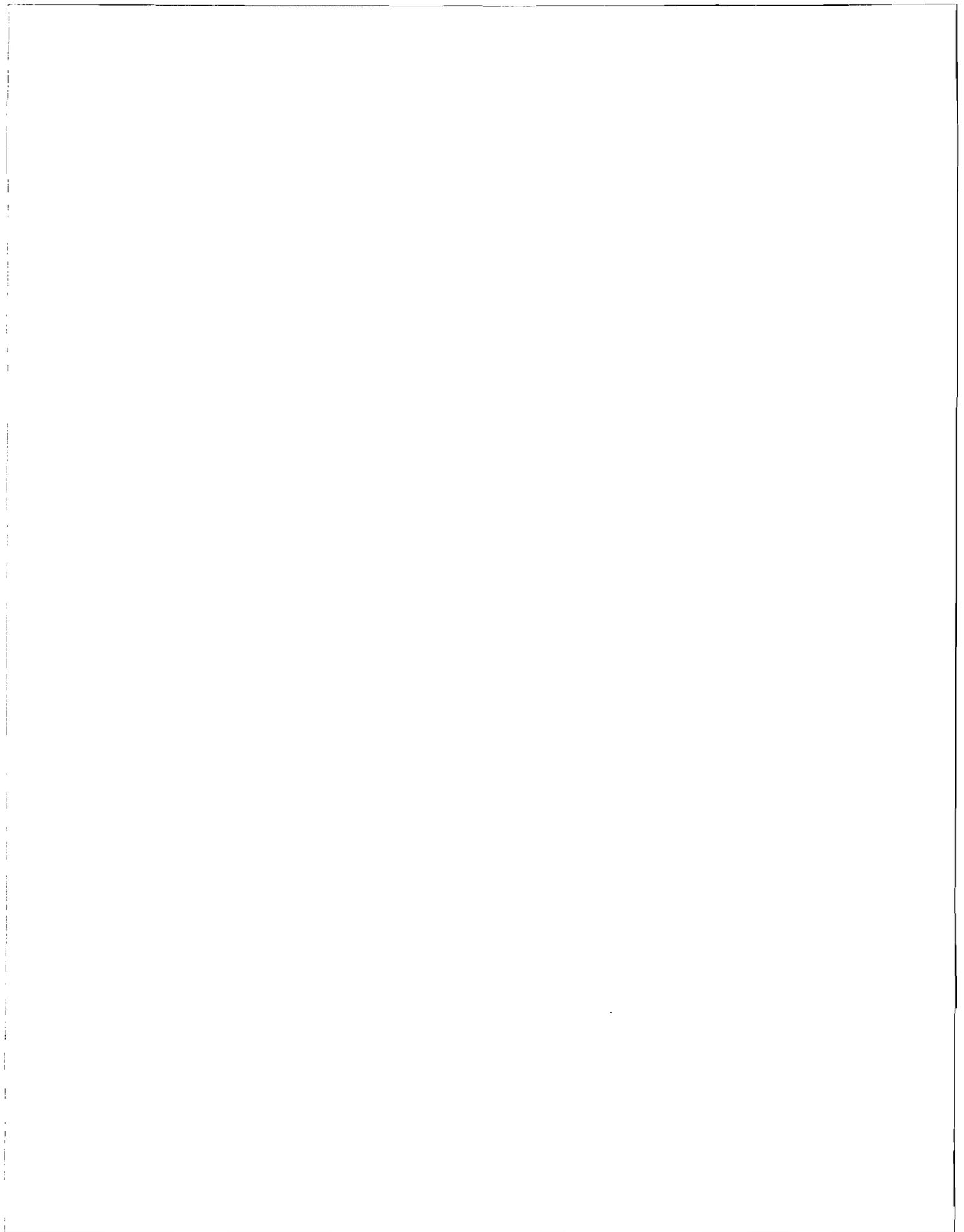




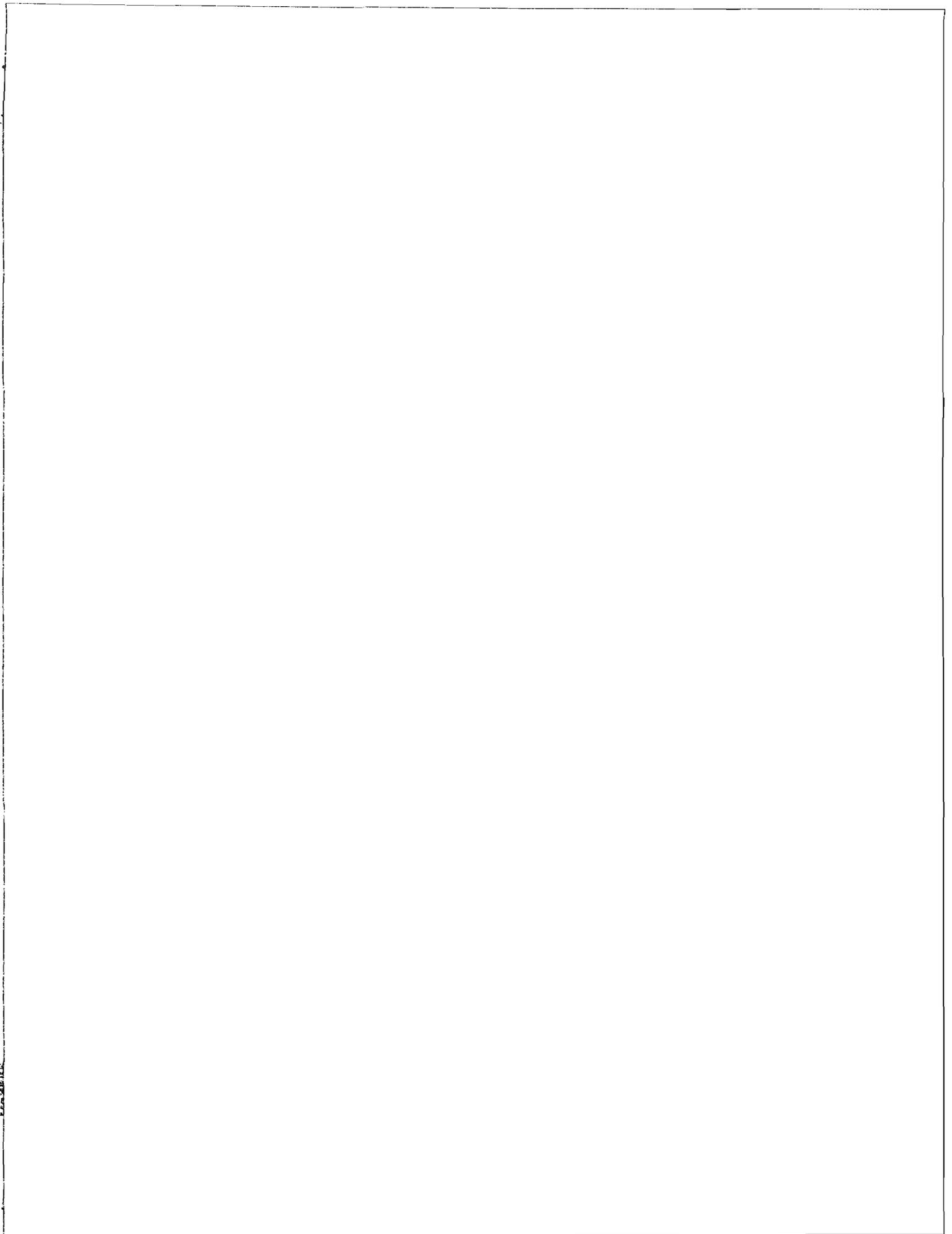


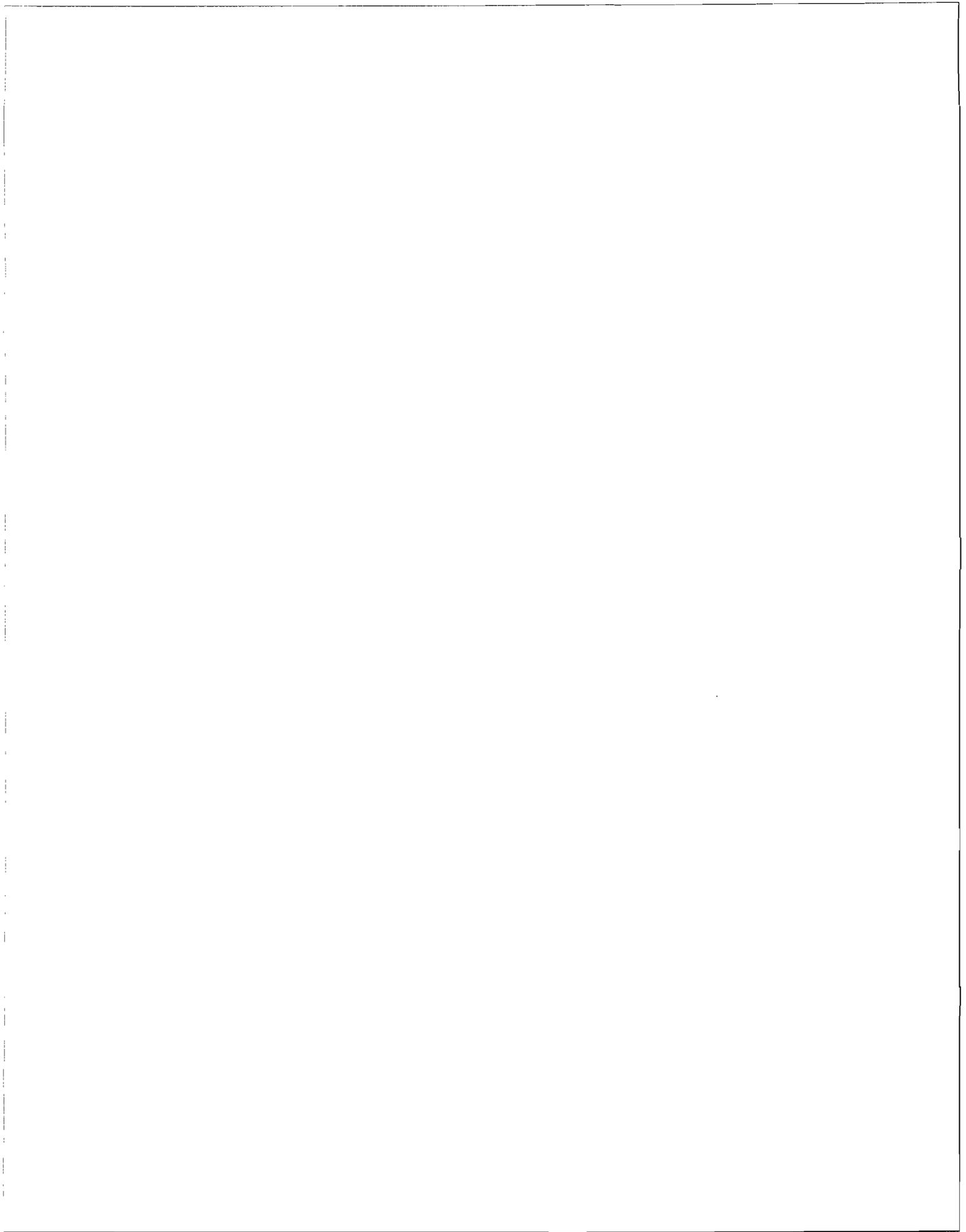


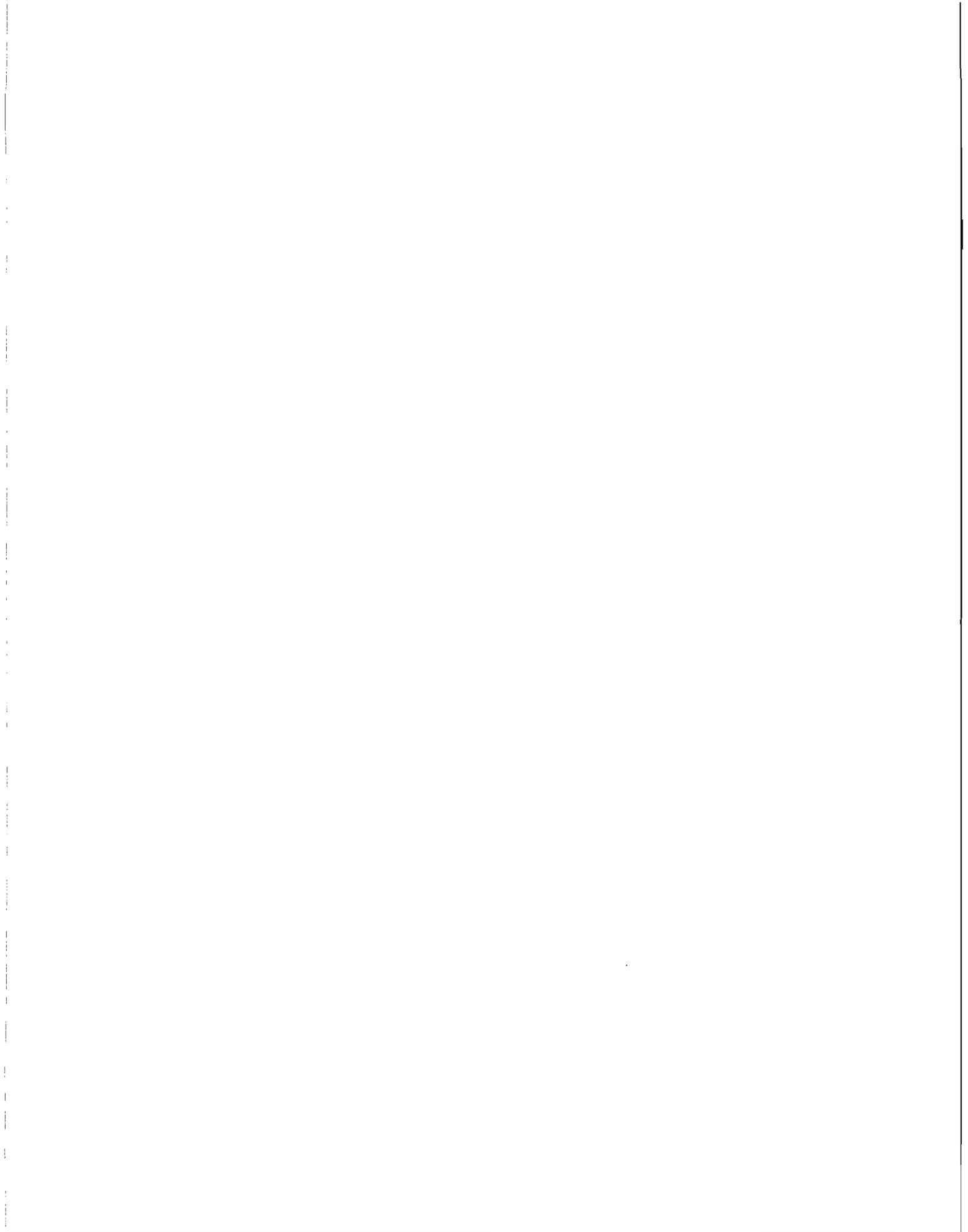


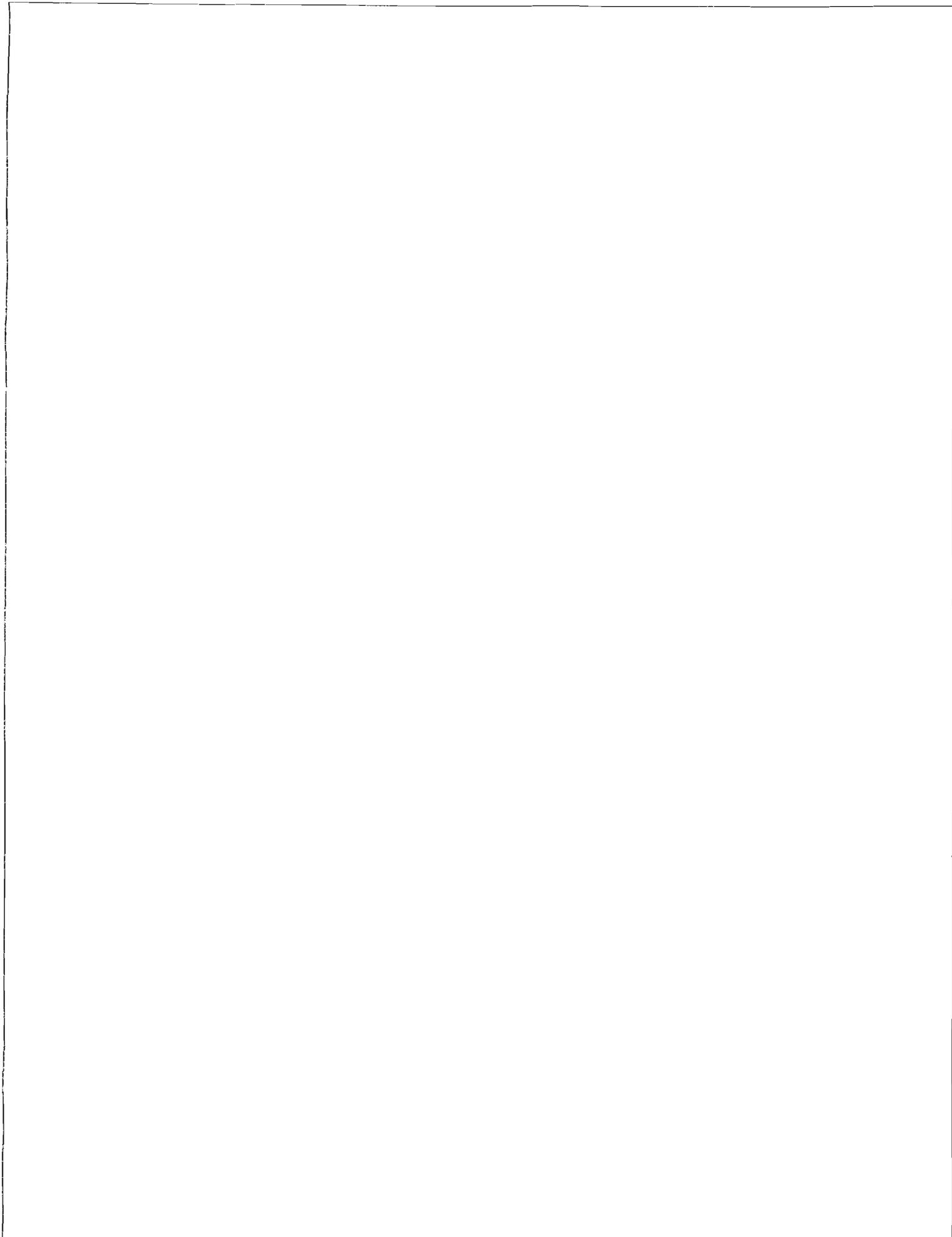


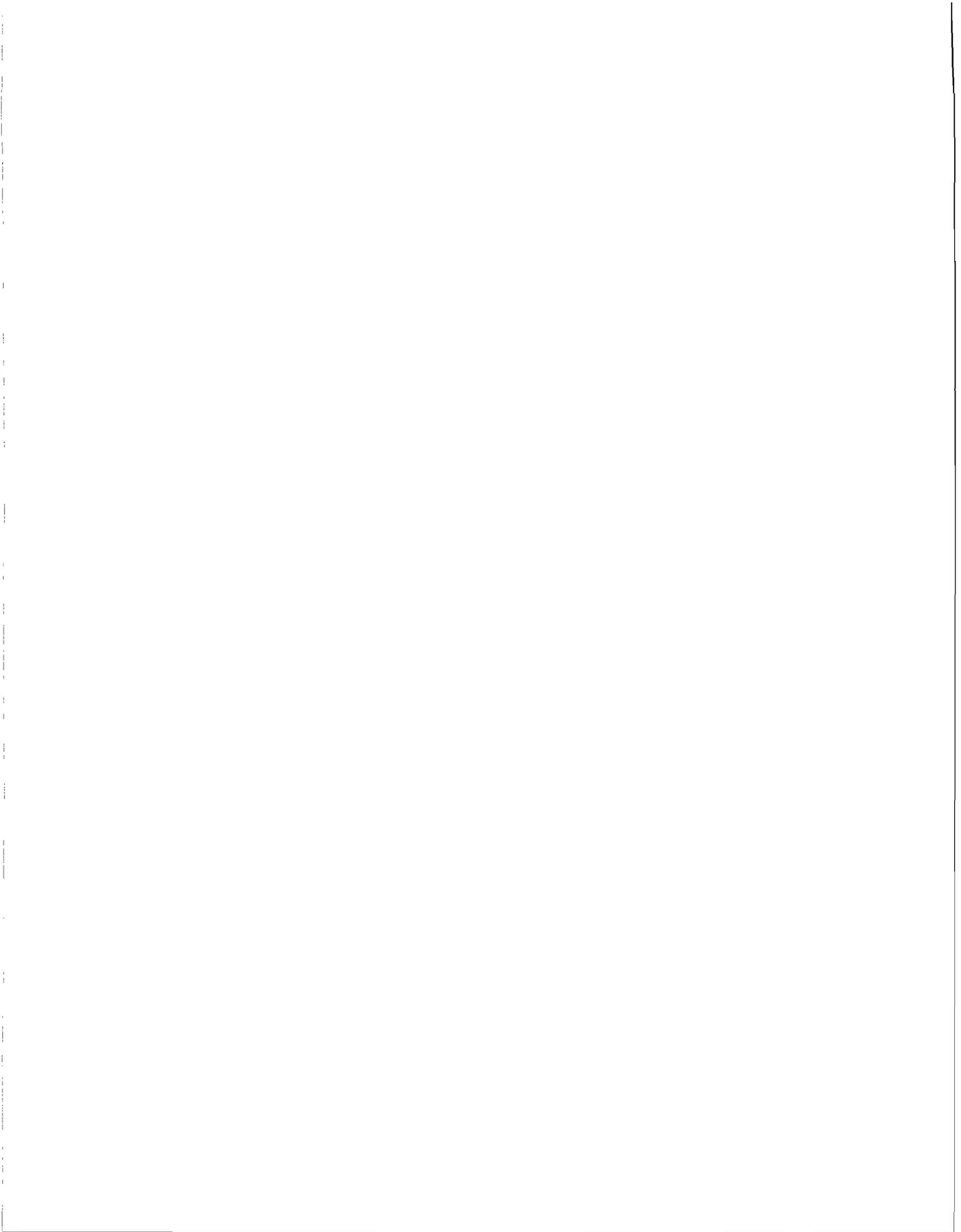


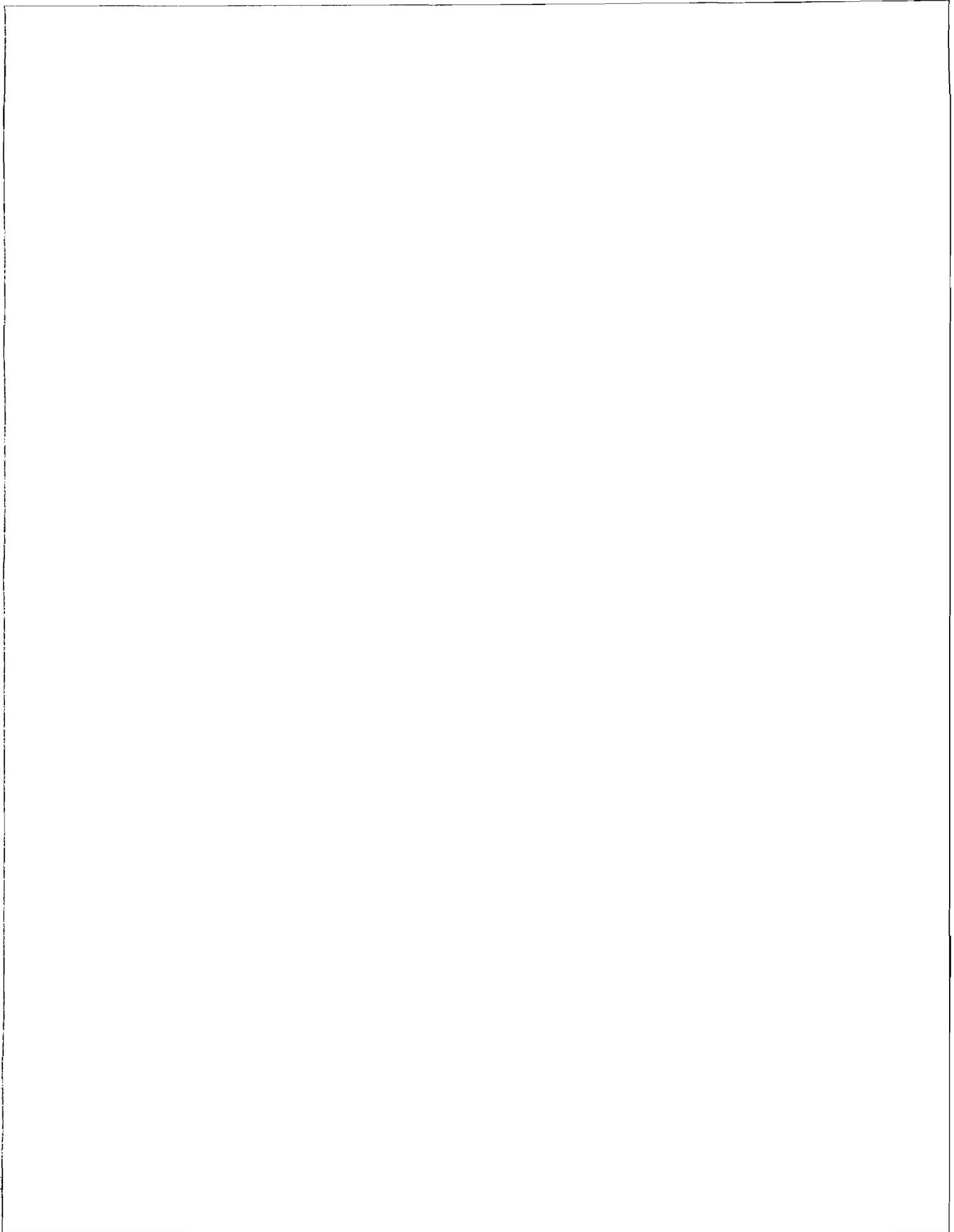




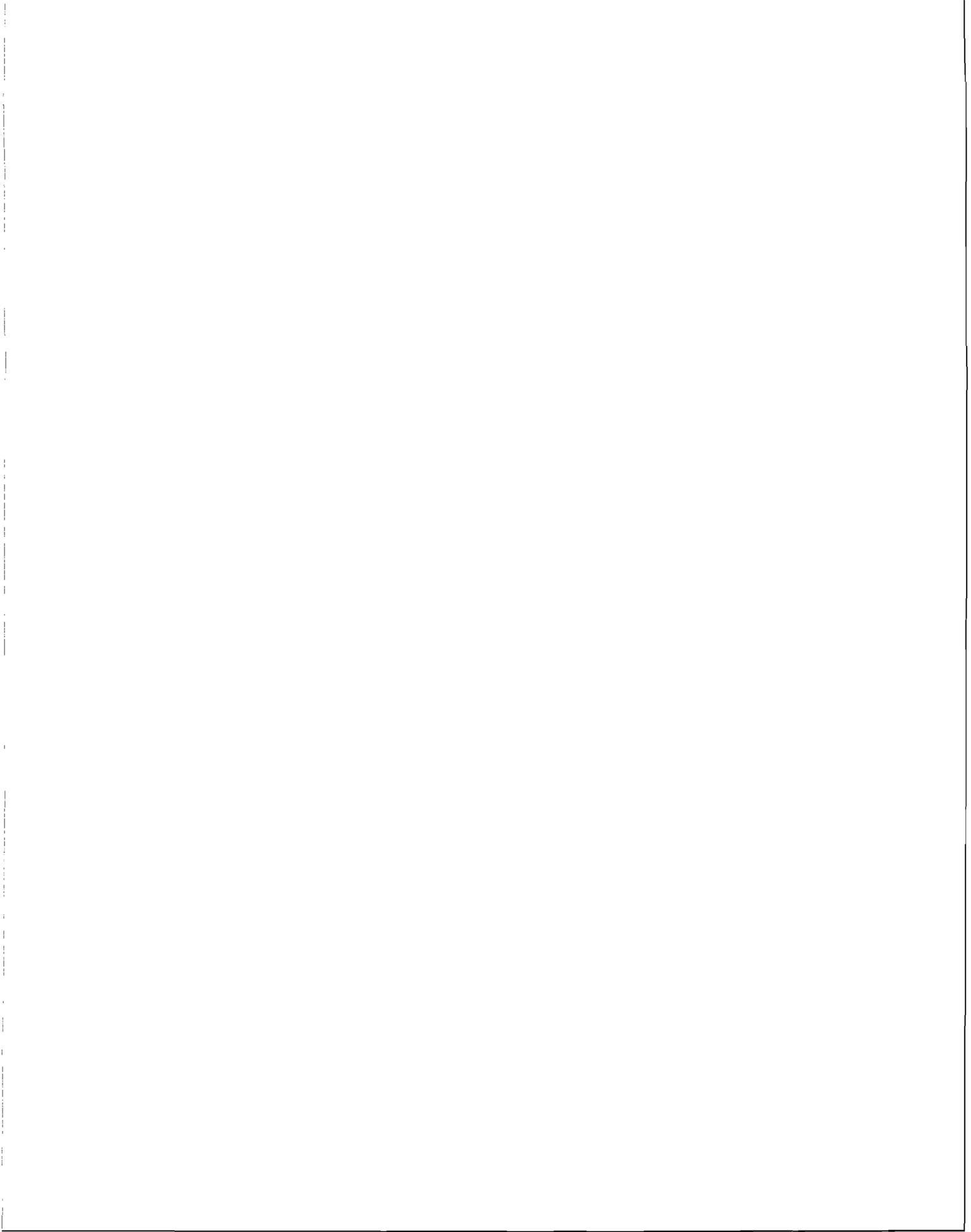


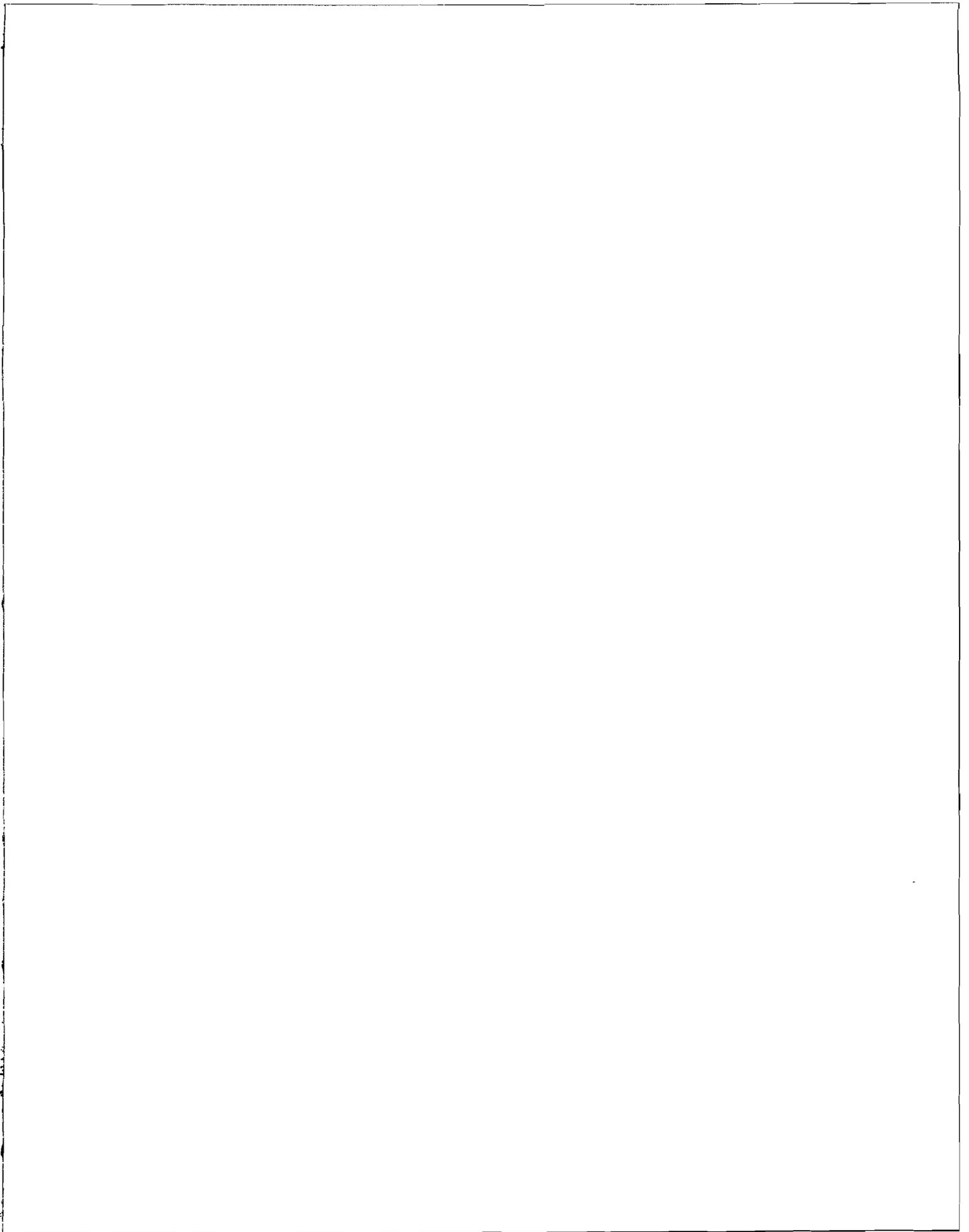


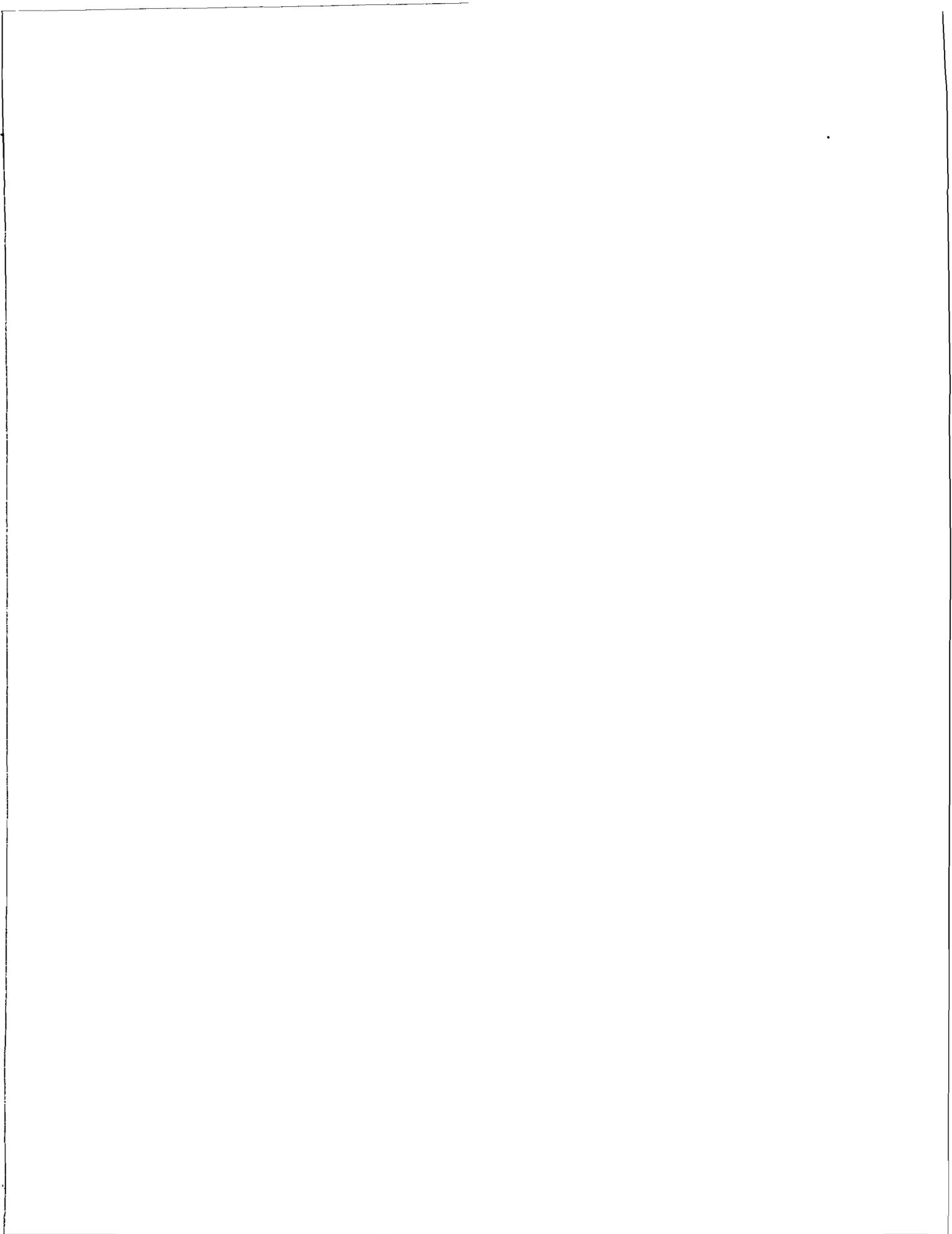


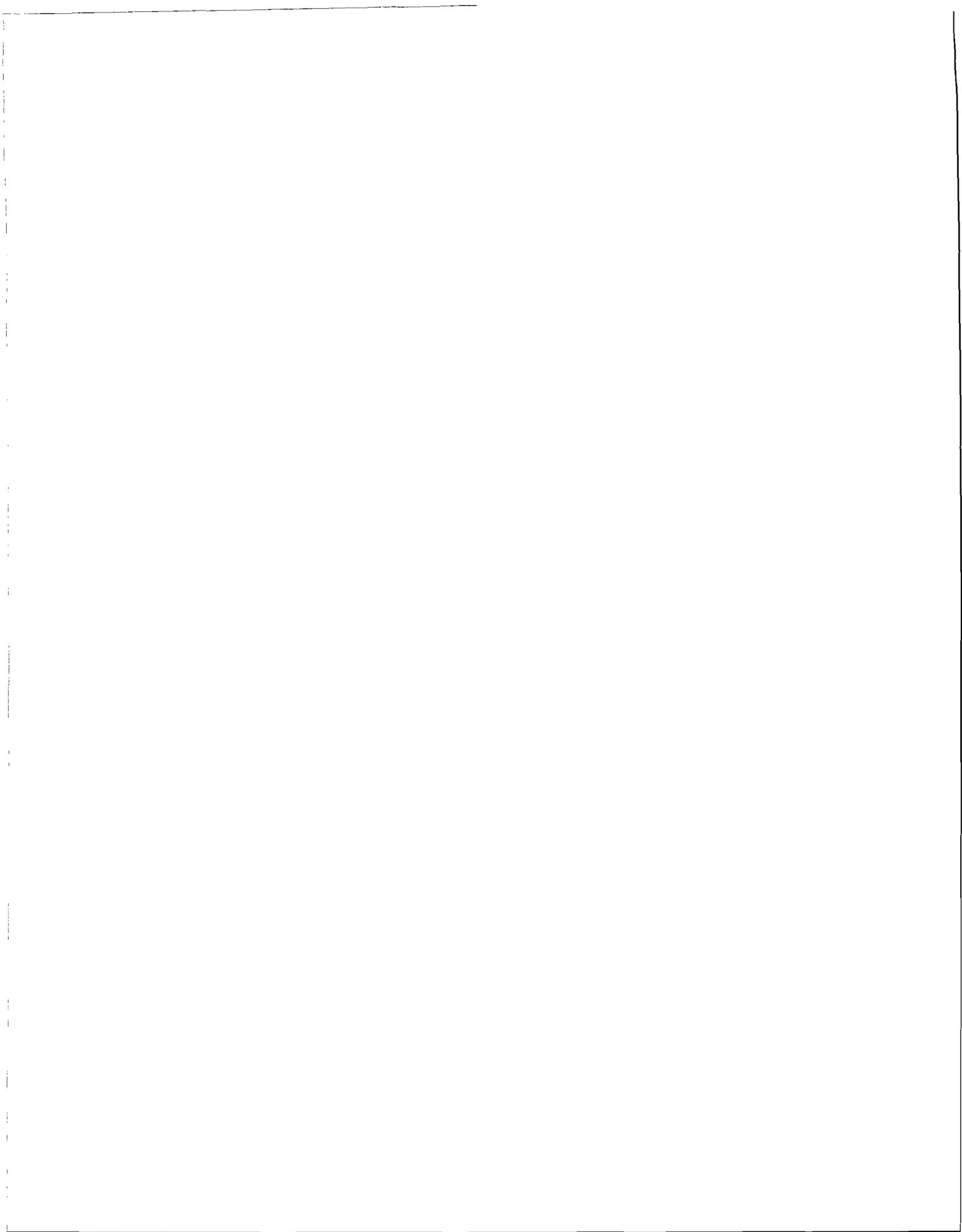


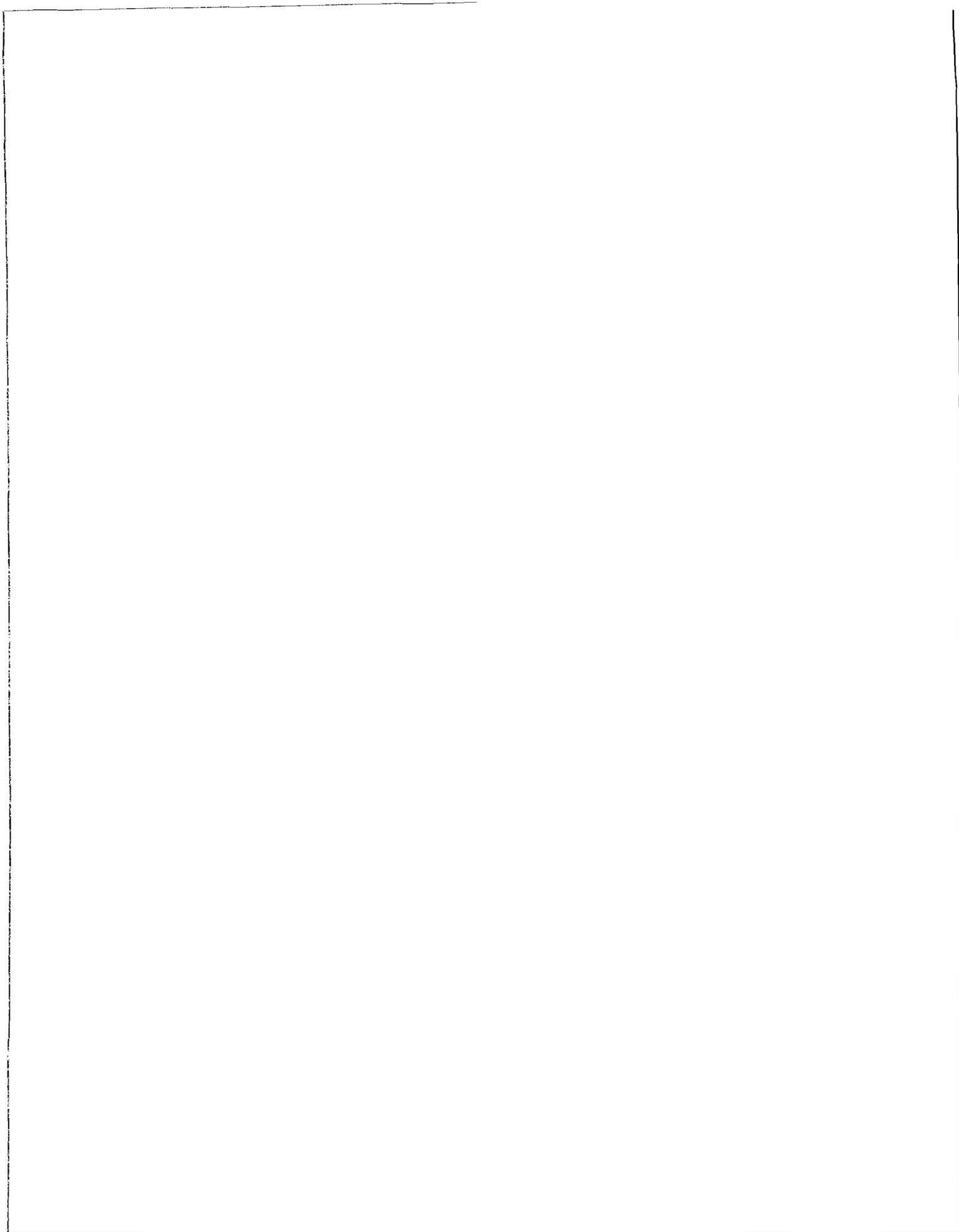












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SEVENTH LECTURE: Ciphony Equipment and Other Specialized Systems

Ciphony Equipment.—You have already had a preview of some of the problems of voice encryption in the discussion of the KO-6. Since by far the greatest weakness in U.S. COMSEC today stems from the fact that almost all of our voice communications are sent in the clear, the business of finding economical secure ways to secure voice transmissions remains a burning issue and is consuming a good part of our current COMSEC R&D effort.

We have to go back to World War II for a look at our first voice encryption equipment:



This looks like a whole communications center or laboratory or something; but it's all one cipher machine. It was called SIGSALLY. If you counted the air-conditioners that had to go with it, it weighed something like 55 tons. It was used over the transatlantic cable for communication between Washington and London. It used vacuum tubes by the thousands, and had a primitive vocoder. It was hardly the answer to the dream of universal ciphony, and was dismantled soon after the war ended.

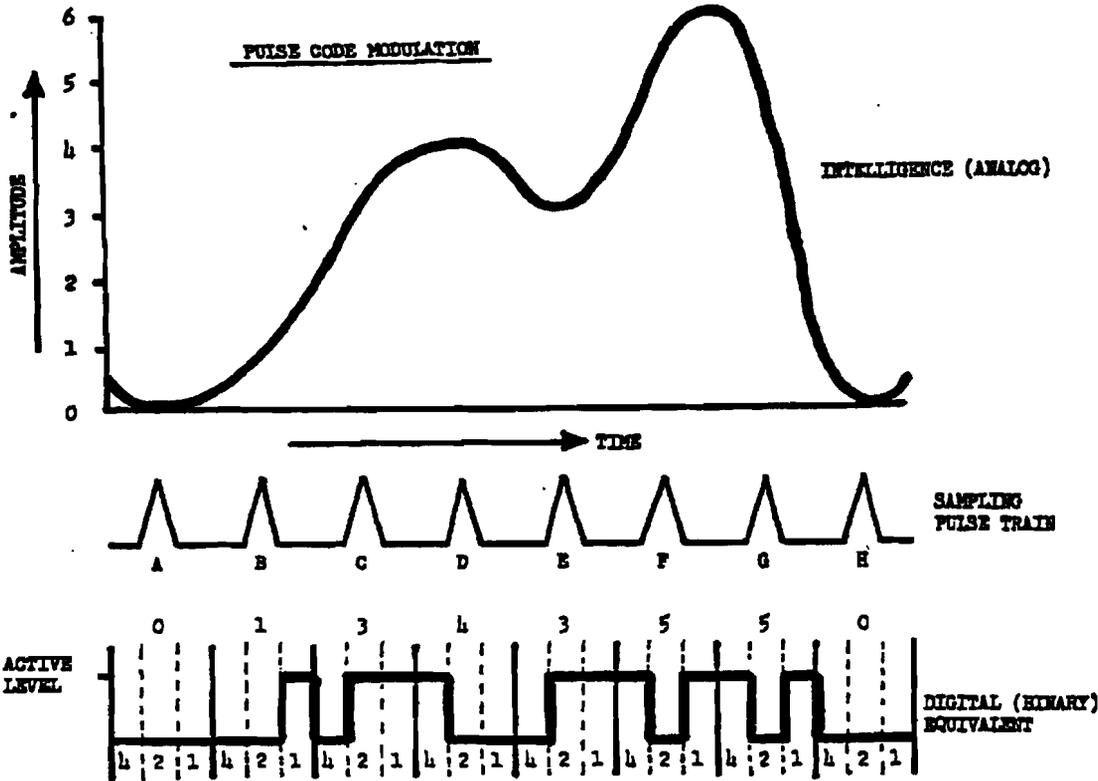
The next ciphony system to come along was called the AFSAY-816. It was designed to operate over microwave links—actually, just one link—between the Naval Security Station and Arlington Hall. Since there was plenty of bandwidth to play with (50 KHz), there were no constraints on the number of digits that could be used to convert speech into digital form. The technique used was

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called Pulse Code Modulation (PCM): conceptually, it involves sampling the amplitude (size) of an intelligence signal, such as one's voice, at fixed intervals of time determined by a high frequency pulse train, then transmitting the values thus obtained in some sort of binary or baudot code. The following illustration portrays these relationships:



The AFSAY-816 used a primitive vacuum tube key generator with bank after bank of shift registers . . . and, for the first time, we were able to put out more key than we could use. So we used it to provide for encryption of several channels of speech simultaneously. Speech quality was good, reliability was spotty, and security, especially in its last years was marginal since it was in about that time frame that we began to be able to postulate practical high-speed computer techniques as a cryptanalytical tool. We hastened to replace the equipment with one called the KY-11. The KY-11 was the first relatively modern key generator of the breed I described in the KW-26.

At any rate, we lived on borrowed time with the AFSAY-816 and on the hope that, because its transmitted signal was fast, complex, and directional, hostile interception and recording would be impracticable.

Don't think for a minute that the same rationale isn't used today for unsecured circuits that happen to use sophisticated transmission techniques. A favorite ploy of the manufacturers of forward tropospheric and ionospheric scatter transmission systems, for example, is to advertise them as inherently secure because of their directivity and because they are beamed over the horizon and theoretically bounce down in only one place. However, because of atmospheric anomalies; it is impossible to predict with certainty what the state of the ionosphere will be at any particular moment. It is because of these anomalies that the reflection of the transmitted signal from the ionosphere is subject to considerable variation and, consequently, subject to interception at an

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unintended location. As a matter of fact, there was a "permanently" anomalous situation over parts of Southeast Asia that caused VHF communications to double their expected range.

The general attitude of this Agency is that *no* deliberate transmission is free from the possibility of hostile interception. The thought is that there is really a contradiction in terms of the notion of an uninterceptible transmission: for, if there were such, the *intended* recipient, your own distant receiver, could not pick it up.

Despite all of this, it is clear that some transmissions are considerably more difficult and costly to intercept than others and some of them carrying information of low intelligence value may not be worth that cost to the potential hostile interceptor. These factors have a lot to do with the *priorities* we establish for providing cryptosystems to various kinds of communications entities.

But, in the case of voice, which is our subject, it has not been any rationale of non-interceptibility which has slowed us down, it is the set of terrifically difficult technical barriers in the way of getting such equipment in light, cheap, efficient, secure form, either for strategic high-level links, as in the case of all the ciphony equipments I've mentioned so far, or for tactical circuits that we will, in due course, cover.

Still, with the advent of the KY-11, it appeared that we had at least one part of the ciphony problem relatively well in hand: that was for fixed-plant, short-range operations where plenty of bandwidth was available for transmission. These fixed-plant, wide-band equipments—all of them—not only could provide secure good quality voice, but had enough room to permit the encryption of several channels of voice with the same key generator. But just as in the case of teletypewriter security devices, there was a need to move ciphony equipment out of the cryptocenter and nearer to the environment where the actual user could have more ready access. In the case of the teletypewriter encryption systems, you will recall, the move was into the communications center where all the ancillary devices and communications terminal equipment and punched message tapes and message forms were readily available. In the case of ciphony, the real user was the individual who picks up the handset and talks—not some professional cryptographer or communicator—but people like you and me and generals and admirals and presidents. So the next need we faced was to provide an equipment which could be remote from both cryptocenter and communications center, and used right in the offices where the actual business of government and strategic military affairs is conducted. This called for machinery that was smaller and packaged differently than any of the ciphony equipment we have talked about thus far. SIGSALLY you remember, weighed 55 tons; the next system weighed a lot less but still needed 6 bays of equipment. The KY-11 was smaller still, amounting to a couple of racks of equipment configured for communications center use. None of them were at all suitable for installation in somebody's office.

The resultant product was called the TSEC/KY-1. The most striking feature it had, in contrast to its predecessor ciphony devices, was that it was neatly packaged in a single cabinet about two-thirds as tall and somewhat fatter than an ordinary safe. Because it was built not to be in a cryptocenter or a classified communications center where there are guards and controls on access to prevent theft of equipment and their supporting materials, this KY-1 cabinet was in fact a three-combination safe that contained the whole key generator, the power supply, the digitalizing voice preparation components—everything except the handset which sits on top.

So, for the first time since World War II with the SIGNIN, we found ourselves building physical protective measures into the equipment itself. The safe is not a particularly good one—hardly any are—but it is adequate to prevent really easy access to the classified components and keying data contained inside. Microwave links or special wire lines were used to transmit its 50 KHz cipher text.

[redacted] and it had the capacity to link up to 50 holders through some kind of switchboard in a common key. The first network was used here in Washington and served key officials of government—the President, the Secretary of Defense, the Secretary of State, the Director, Central Intelligence Agency, and some others. We soon found that the equipment needed to be installed not only in key government offices, but in the private residences of key officials as well, so that they could consult securely in times of crisis night or day. I think the first such residence was

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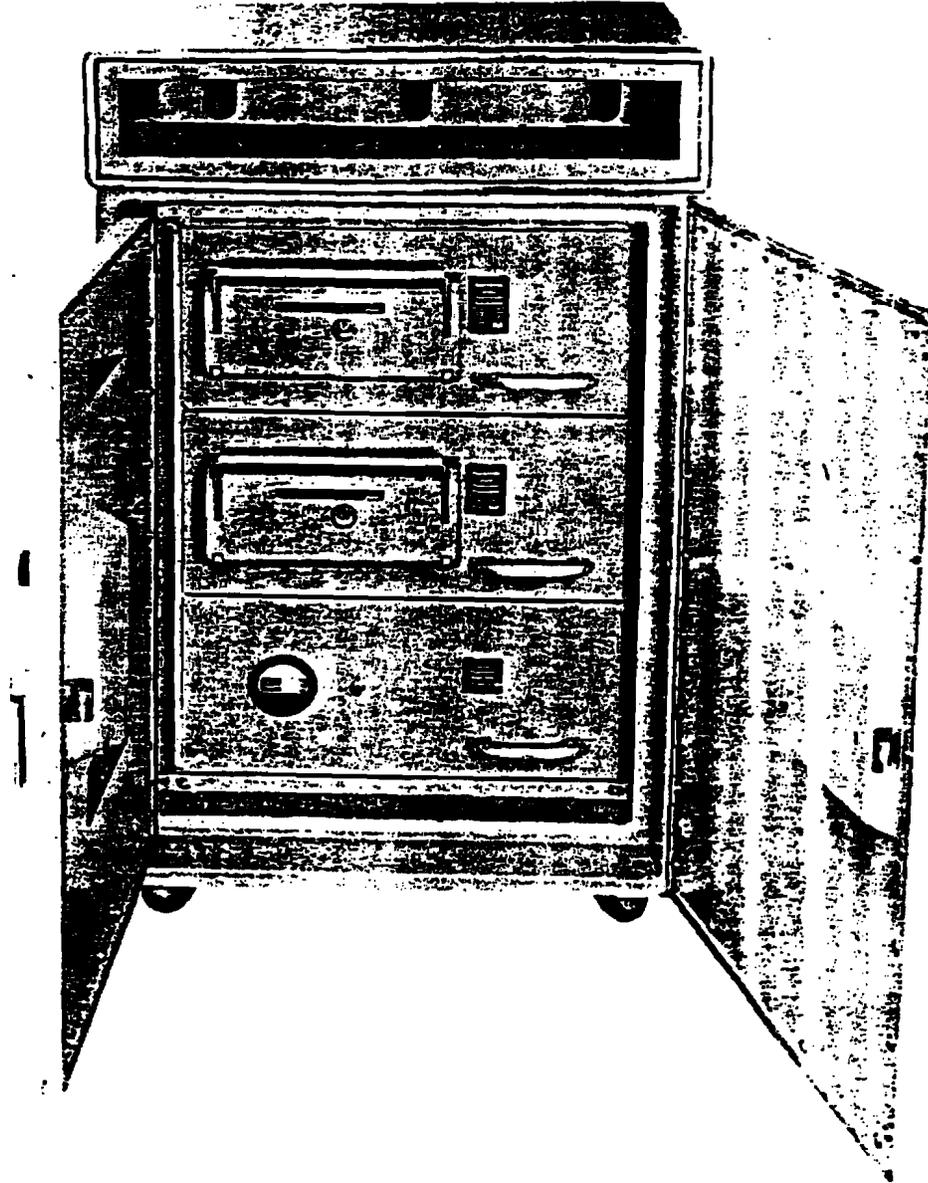
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President Eisenhower's Gettysburg address: later such equipments were used in the homes of a number of other officials.

The KY-1 had some limitations, as almost all first tries at a new requirement seem to: it was essentially a push-to-talk system which annoys most users and makes it impossible to interrupt conversations. Eventually, the cryptanalysts discovered some new possible attacks that lowered our confidence in its security and so the KY-1 was retired in early 1967. This KY-3 is the follow-on equipment to the KY-1. It provides a duplex (no push-to-talk) capability and some security and operational refinements.



This is perhaps as good as a place as any to go off on another of the tangents that seem to characterize these lectures. As we have been following the evolution of U.S. cryptography, I have talked

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quite casually of new equipments coming into our inventory and old ones fading away. In retrospect, the demise of the obsolescent, inefficient, and insecure systems seems natural, easy, inevitable, and relatively painless. But the fact of the matter is that it is usually quite difficult to get the users to relinquish any equipment once it is solidly entrenched in their inventories—especially if it works well, as in the case of the KY-1; but even if it doesn't, as in the case of the KW-9. The reluctance to junk old systems stems from a number of causes, I think. First of all, they represent a large investment; secondly, the users have developed a supporting logistic base for the systems, have trained personnel to operate and maintain it—they've used it. Finally, the introduction of a new system is a slow and difficult business requiring new budgetary and procurement action, new training, the establishment of a new logistics base, and—increasingly these days—a costly installation job to match the new system to the facility and communications system in which it is to be used. Because of these problems, our "equipment retirement program" is a halting one, and only when there are very grave security shortcomings can we actually demand that a system be retired on some specific date. Well, back to ciphony systems.

With all these developments, we are still talking about equipment that weighs several hundred pounds, is quite expensive, and which is limited to specialized and costly communications links. Except in the case of the KO-6, these links are relatively short range.

So, at the same time these wide-band fixed-plant equipments are being developed, we were working on something better than the KO-6 to satisfy long-range, narrow-band communications requirements, something that could, hopefully, be used on ordinary telephone lines or on HF radio circuits overseas. (Ma Bell's telephone system, you understand, has a bandwidth of only 3 KHz—and still has a few quick and dirty WW II links in the mid-west with only a 1500 hertz bandwidth. This situation, as I have said, sharply limits the number of digits we can use to describe speech to be encrypted on such circuits with a consequent loss of quality of intelligibility.)

The equipment which evolved is called the KY-9.

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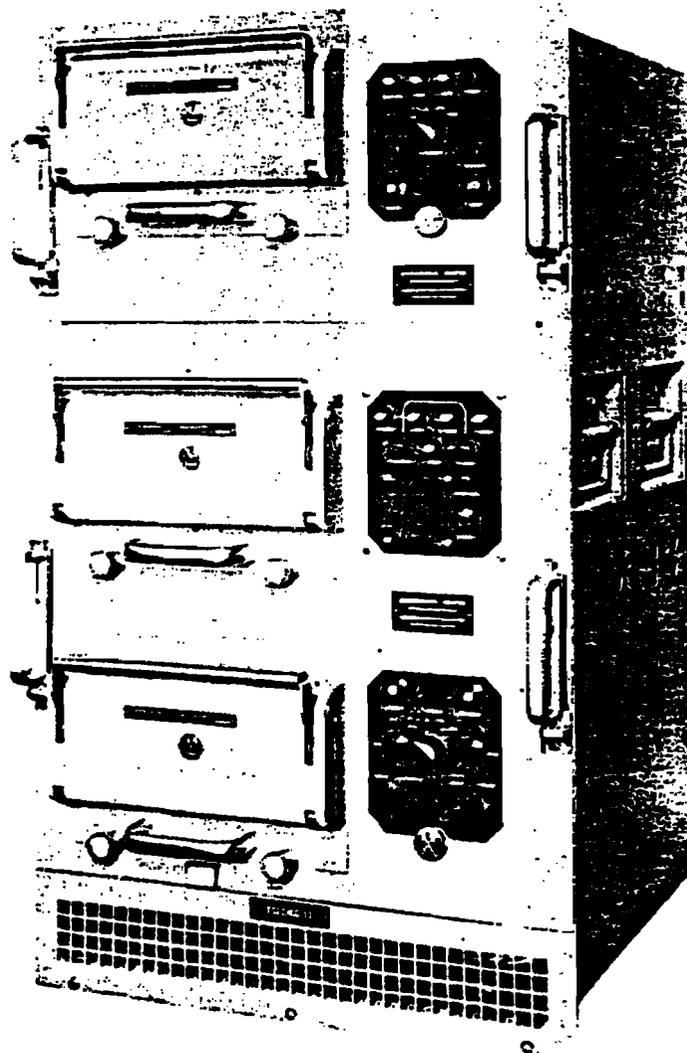
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The KY-9 used a vocoder as did its narrow-band predecessors, but a more sophisticated one than had been developed thus far. It was the first of the vocoders to use transistors instead of vacuum tubes, so that the equipment could be reduced to a single cabinet. But transistors were in their infancy; and the ones that went into the KY-9 were hand-made and expensive. Again the equipment was packaged into a safe so that it could be located in an office-type environment. Well, we were getting there: we could use an ordinary telephone line with the KY-9, but the speech still sounds artificial and strained because of that vocoder, and . . . you . . . must . . . speak . . . very . . . slowly . . . and . . . distinctly and you must still push to talk. And besides all that, this bear initially cost on the order of \$40,000 per terminal which put it strictly in the luxury category. About 260 KY-9's are in use for high-level, long-haul voice security communications. The majority of the KY-9 subscribers are now being provided this secure capability through use of the Automatic Secure Voice Communications (AUTOSEVOCOM) system; however, it is anticipated that the equipment will remain in use at least through FY-74. Beyond FY-74, the equipment may be declared excess and stored for contingency purposes.

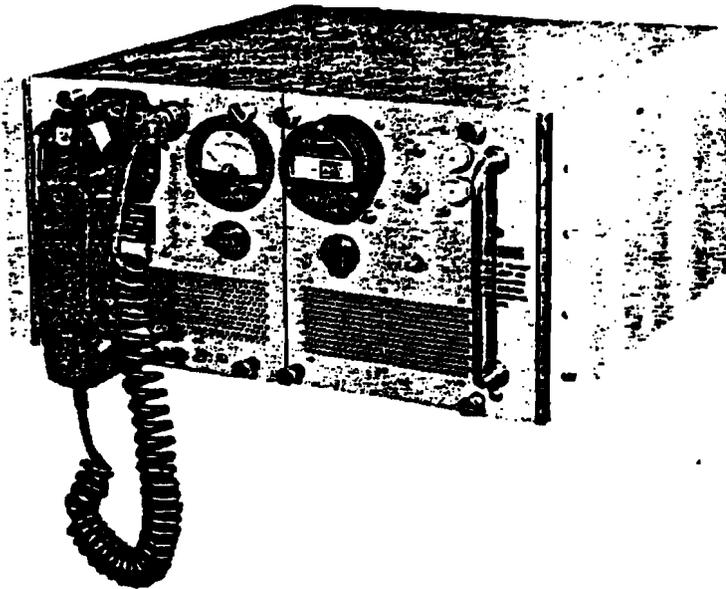
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The best and newest long-haul voice equipment uses none other than our multi-purpose friend, the KG-13. Nobody came along with a nice vocoding speech digitalizer to hook into this key generator, and there's really not much call to process speech this way unless you're going to encrypt it, so we wound up—*again*—having to build some of the ancillary equipment ourselves. This equipment is called the HY-2—remember, the H stands for *ancillary*, the Y for *speech encryption*. So the combination referred to as the KG-13/HY-2 is the system we are now counting on to serve the long-haul voice requirement.



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Again, a vocoder was used, and this sounds the best yet, although it still can't match the voice quality that wide-band systems have. This package is not in a safe, and is not suitable for office installation, but it seems to satisfy most of the other long-haul requirements well and does so fairly cheaply for the first time.

Before we talk about tactical voice security equipment, there is a subject related to the big fixed-plant voice equipments we ought to talk about. That's the subject of "approved" circuits. Way back with the KO-6, we were having difficulty getting officials to leave their offices and walk to a cryptocenter to use a secure phone. The solution lay in carrying the system or at least the telephone handset (which is all he really needs or cares about) to him. This involved running a wire line from an office to the cryptocenter or secure communications center. The difficulty with this solution is twofold: in the first place there was and is a long-standing Executive Order of the President governing the way classified information may be handled, transmitted, and stored; and in the case of TOP SECRET information, this order forbids electrical transmission *except in encrypted form*. Of course, the informations in the clear, not encrypted, until it reaches the cryptomachine, and this meant that any time one placed that handset remote from the machine, the user, by "law" had to be restricted to conversations no higher than SECRET. This is difficult to legislate and control, and reduces the usefulness of the whole system. The second difficulty in this situation stems from the security reasoning lying behind that Executive Order. The reasoning was, and is, that it is extremely difficult to assure that no one will tap any subscriber line such as this, if it is not confined to a very carefully controlled area like a cryptocenter or classified communications center. It means that if you are to use these subscriber lines in some government installation, the whole building or complex of buildings must be extremely well guarded, access carefully controlled, or personnel cleared or escorted all the time. Controls such as we have here are simply not feasible in a facility such as the Pentagon or on a typical military post: yet it is in just such environments that these protected wire-lines may be needed.

Some special rules govern communications used to support SIGINT operations, and these rules have been interpreted to permit TOP SECRET traffic such as we use on the grey phone system here—provided certain physical and electronic safeguards are enforced. The JCS applied the same sort of criteria in staffing an action which permitted TOP SECRET information to be passed in the clear over wire lines when certain rigid criteria are met. Until this action went through, we were unable to make full use of the ciphony capability we now have in systems such as the KG-13/HY-2,

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and subscribers were held to SECRET unless they were essentially co-located with the crypto-equipment itself.

Tactical Ciphony.—MC's for tactical ciphony equipment—be they broad-band, narrow-band, or somewhere in between—have existed since before this Agency was created. But the difficulties were terrific. To have tactical usage on field telephones and radio telephones and military vehicles and, especially, in aircraft, the equipment had to be truly light, small, and rugged; and had to be compatible with a large variety of tactical communications systems most of which are not compatible among themselves. In the case of aircraft requirements, there's an old saying that the Air Force will reject any system unless it has no weight, occupies no space, is free, and adds lift to aircraft. We were about ready to believe this in the late fifties when we had gotten a tactical ciphony device, the KY-8, down to about 2/3 of a cubic foot, and it was still not accepted, mainly because it took up too much room. The ironic part of this sad story is that the cryptologic portion of the hardware uses only a modest amount of space: its power supplies and the digitalizers for speech that use up the room. The Air Force did give that small equipment, the KY-8, a good try in high performance aircraft like F-100's: it worked fairly well, but sometimes reduced the effective range of their radios about 5%, a degradation of their basic communications capability they simply could not afford. Besides, the problem of lack of space proved very real and they had to rip out one of their fire-control radars to make room for the test equipment.

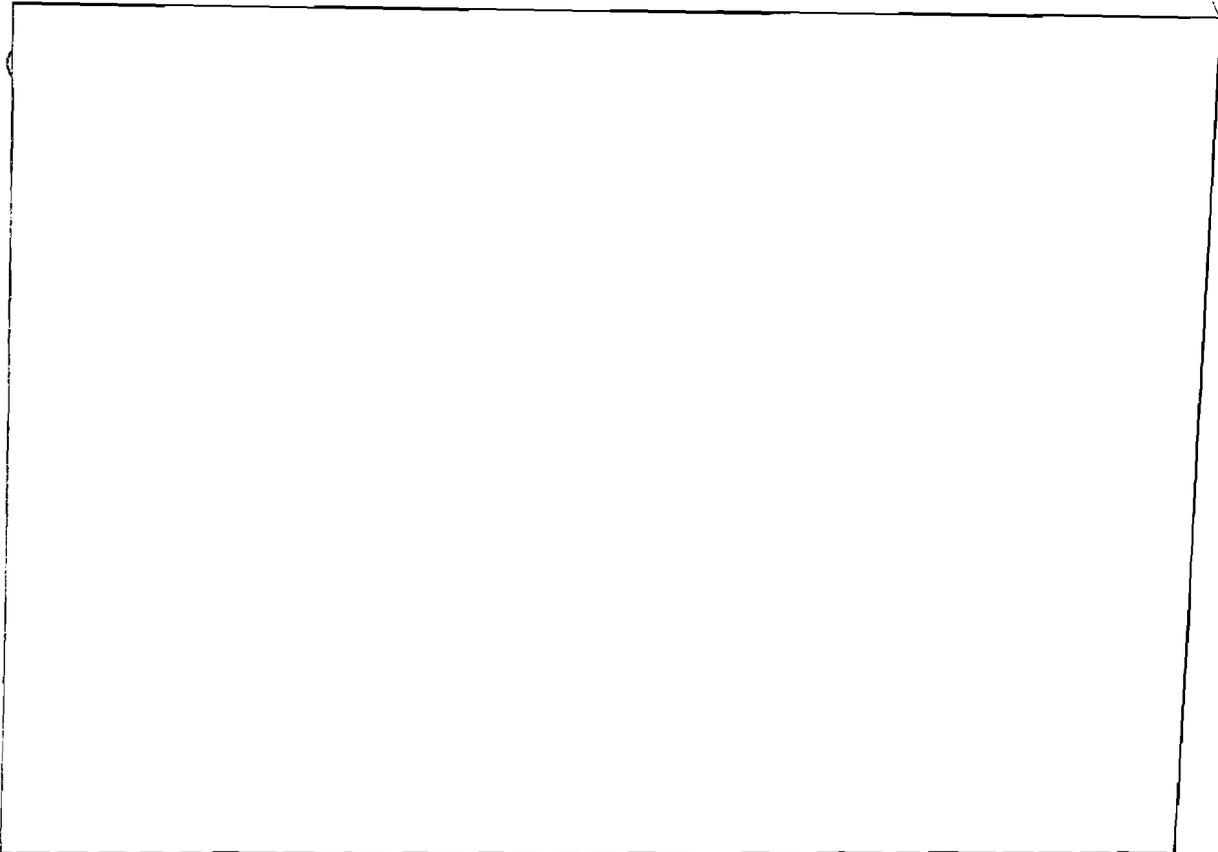
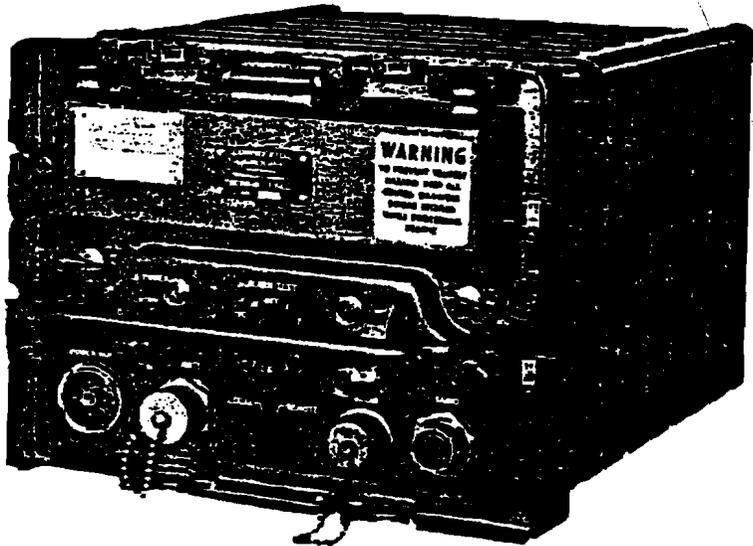
Then the Army decided it could use the KY-8, mounting it in jeeps and other wheeled vehicles where space was not so critical as in aircraft. We had attempted to make a ground tactical ciphony equipment for Army, called the KY-4, but it didn't pan out; and the Army had independently tried to develop a tactical voice device that was equally unsuccessful. So Army bought a batch of KY-8's and they and the Marines became the principal users, even though it was really originally designed for aircraft.

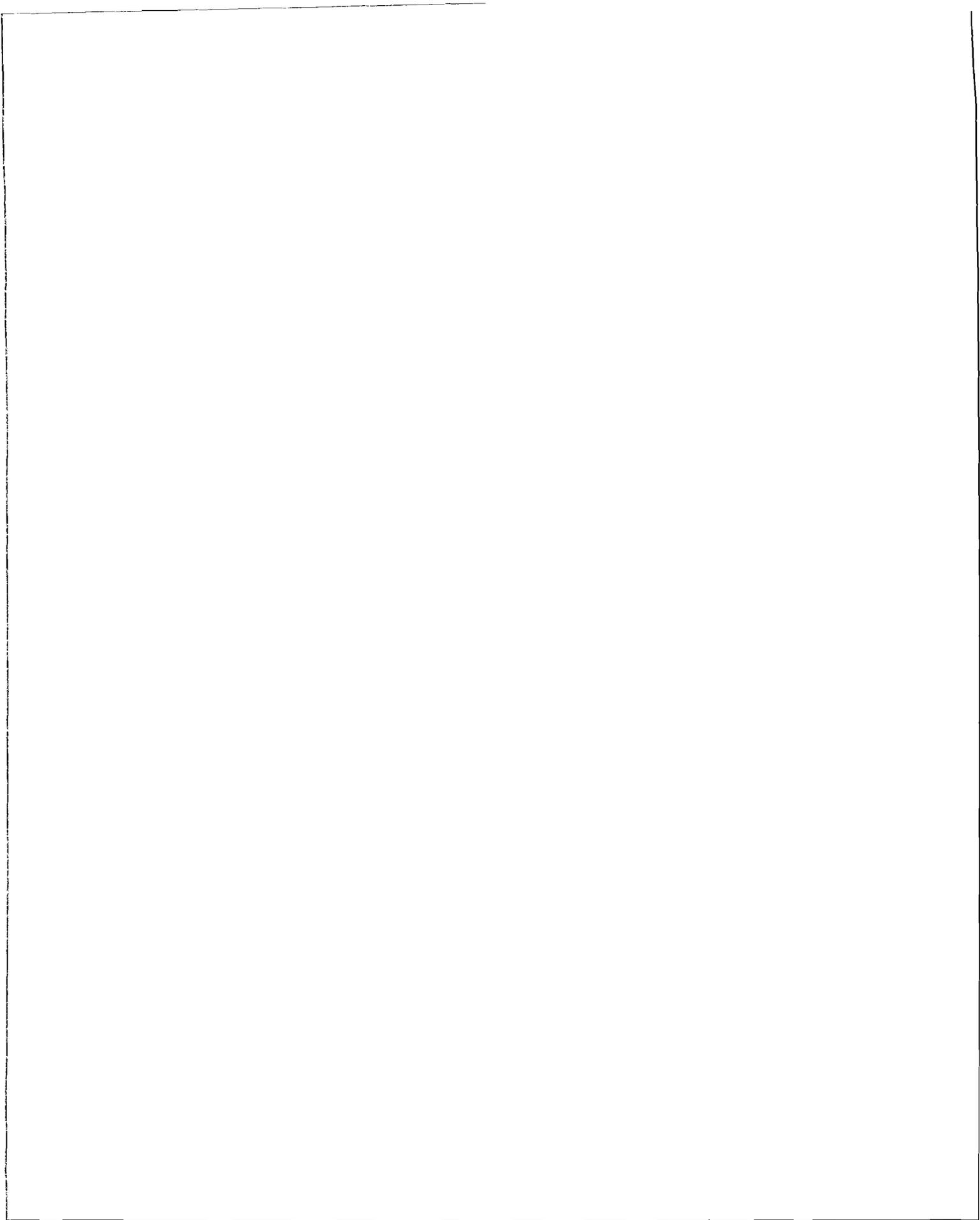
There's another point about the KY-8. I've made it sound as if over-choosy users have been the only cause for its slowness in coming and limited use. That's not quite the case. There were some security problems—the compromising emanation business again—that slowed down our production for some time: we finally got going full blast on this equipment by cancelling out most of the delaying features in the contract associated with the radiation problem, accepting this possible security weakness as a calculated risk, and placing some restrictions on where the equipment could be used to minimize that risk.

Today we have a family of compatible, tactical, speech security equipments known as NESTOR—the KY-8/28/38. The KY-8 is used in vehicular and afloat applications; the KY-28 is the airborne version; and the KY-38 is the portable or man-pack model. There are currently about 27,000 NESTOR equipments in the U.S. inventory. No further procurement of NESTOR equipments is planned because the VINSON equipment is intended to satisfy future requirements for wide-band tactical voice security.

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From the operational point of view, the effect of a system such as this is that any receiver can pick up a transmission in mid-stream just as KW-37 receivers can, but without the elaborate clocks and high-speed catch-up mechanisms.

We have now covered the major equipments and principles in use today. The big systems are:

For Literal Traffic:	The KL-7/47
For Teletypewriter Traffic:	The KW-26, KW-37, KW-7
For Ciphony:	The KY-3, KY-8, KY-9 (KG-13/HY-2)
For Multi-purpose:	The KG-3/KG-13

[REDACTED]

We have also talked of a number of electro-mechanical equipments that are dead or dying: one-time tape systems, and the KO-6 with its geared timing mechanism being most representative.

The variety of systems which have evolved has stemmed from needs for more efficiency, speed, security and the like: but, more fundamentally, from (1) the need to encrypt different kinds of information—literal traffic, TTY, data, facsimile, TV, and voice, (2) the need to suit encryption systems to a variety of communications means—wire lines, narrow-band and broad-band radio circuits, single-channel and multiplex communications, tactical and fixed-plant communications facilities; and (3) the need to suit these systems to a variety of physical environments.

Specialized Systems.—There are two other types of systems now in the inventory beyond those I have described that I want to touch on briefly. I have left them till last because they are among the most specialized and have as yet seen relatively little use in comparison with the big systems we have talked about. The first of these is the KG-24, designed for the encryption of TV signals—division we call it. With the requirement for encrypting TV signals, we found ourselves faced with the problem of generating key at extremely high speeds, even by computer standards. So far, the fastest system I have described to you was the old AFSAY-816 with a bit-rate of 320 KHz—but this took six bays of equipment and had security, operational, and maintenance problems almost from the outset. Among the modern systems, the KG-3/13, with bit rates up to 100 kilobits was the fastest. But, as you know, with your home TV set, you tune to megahertz instead of kilohertz and it takes millions of bits each second to describe and transmit these TV signals. The KG-24 does it, and in one fairly large cabinet.

[REDACTED]

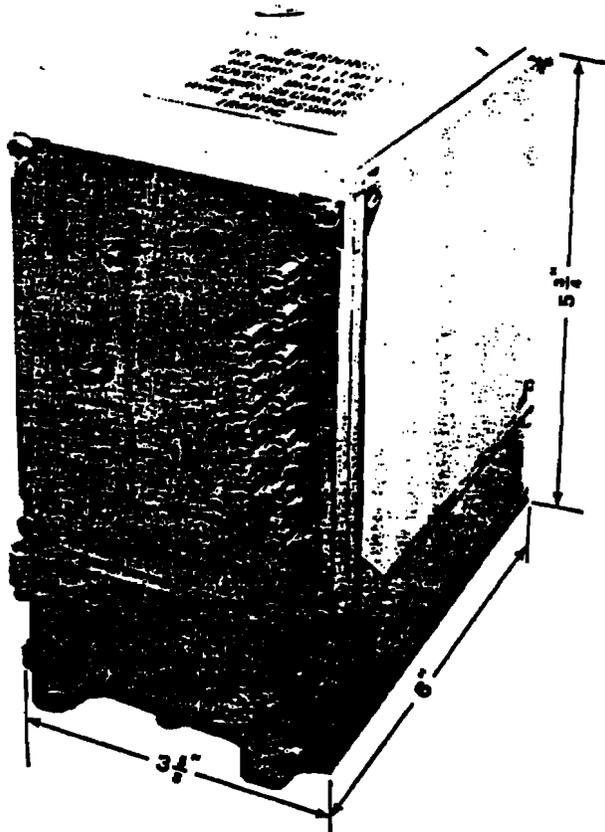
But there are only 6 (V-1) and 7 (V-2) models in existence, and further procurement is not planned. The main thing wrong with it is simply that it costs much too much.

The second type of modern specialized system I want to talk about is the family of equipment designed specifically to go into space vehicles. There were some obvious and some not-so-obvious difficulties that had to be met in the design of these equipments. One obvious problem was to make them small enough, and this requirement gave a big push to our general work in the micro-miniaturization of hardware. The second problem was also inherent in space technology—that was the need for extreme reliability. For unmanned surveillance satellites, if the system fails, you can't call a maintenance man. So we were faced with more rigid specifications and quality controls than we

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had ever seen before. The third problem has to do with the extraordinary complexity of satellite systems as a whole. We have found it next to impossible to provide decent crypto-equipment for our customers without a very full understanding of the whole communications and operations complex in which they are to operate. With our limited manpower, this has proven difficult enough to do with modern conventional communications systems and switching complexes on the ground but, for the space requirements, we had to educate our people to speak and understand the language of this new technology; and we have a little group who live and breathe this problem to the exclusion of nearly everything else.

And finally, we had to throw a lot of our basic *methodology* out the window. Every machine I have talked to you about so far, without exception, is built to have some of its variables changed at least once each day, and some of them more often. Everyone of them is classified and *accountable*: can you imagine how a crypto-custodian, charged with the specific responsibility of vouching for the whereabouts of a classified machine or classified key felt upon watching one of his precious items go rocketing off into space? Of course, we decided that we ought to "drop" accountability at the time of loss, although "lift" accountability might have been a more appropriate term. In any event, here's one of these key generators we use in space:



What we built into it was a principle that would put out a key that would not repeat itself for a very long period of time—weeks or months or years, whatever was required. Actually, with many of these new key generators, the matter of assuring a very long unrepeated sequence or, as we call it, a *long cycle*, is not so difficult. Even something as the KO-6 with its geared timing mechanism and just six metal disks would run full tilt for something like 33 years before the disks would reach

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their original alignment again, and the daily change of its key was incorporated mainly to limit the scope of any loss that might occur—that business of supersession and compartmentation again.

So far, these things are working well—one technical security problem has been encountered.

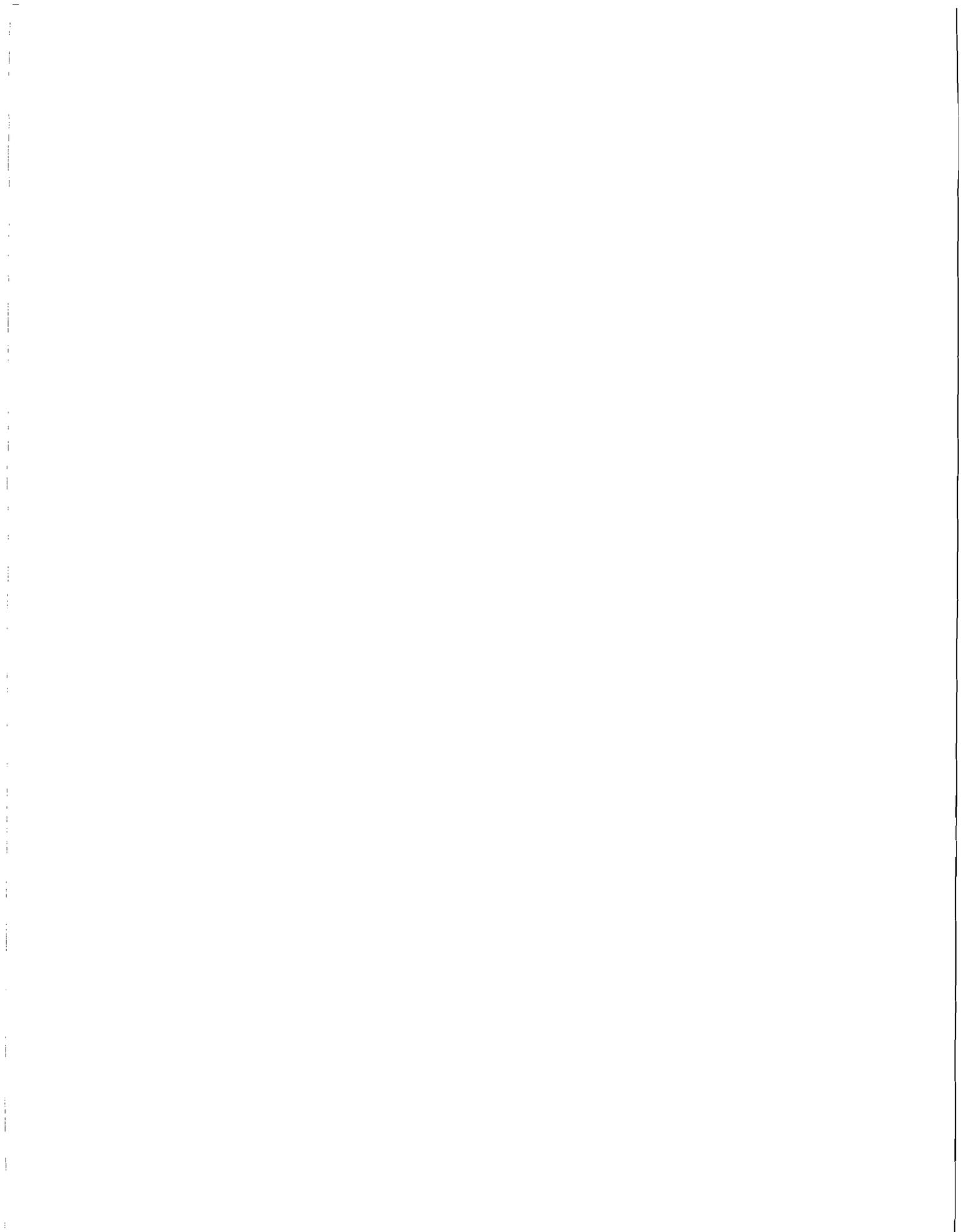
We have several such systems now. We don't talk about them very much because the whole question of surveillance satellites is a very sensitive one and, of course, that's what these are used for.

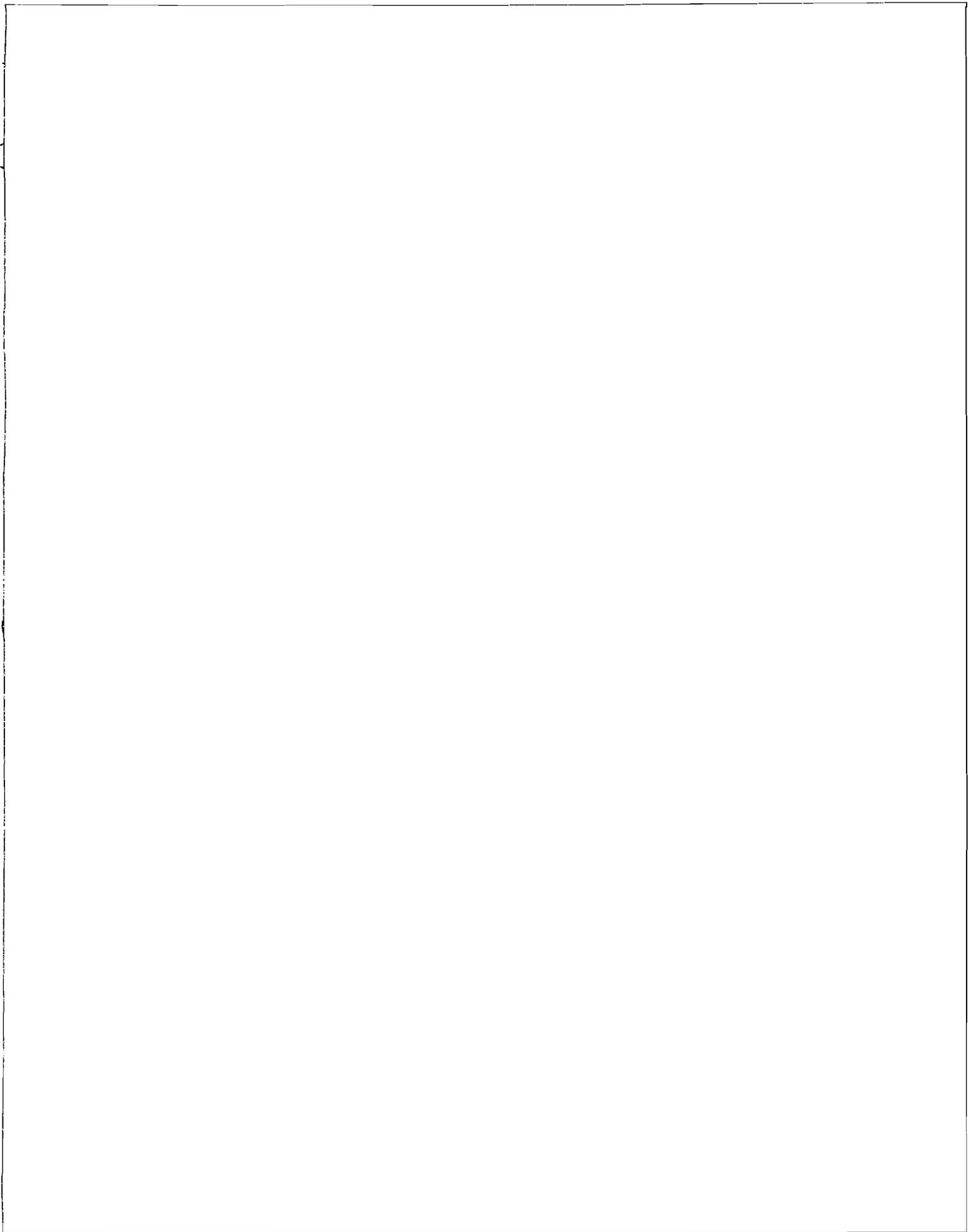
Before moving on, there are a few more things you ought to know about the nomenclature system and the equipment development cycle we have touched on from time to time already. The first point is that the TSEC nomenclature we have is *not* assigned to an equipment until it has been worked on by R&D for some time and they have done feasibility studies and have, perhaps, hand-made all or portions of it to figure out the circuitry or mechanical linkages to see if the thing will work. These very early versions are called "bread-board" models, and are likely to bear little or no resemblance to the final product. R&D assigns cover names to these projects in order to identify them conveniently—the only clue to the nature of the beast involved is contained in the first letter of what ever name they assign. The letters generally correspond to the equipment-type designator in the TSEC scheme—with "W" standing for TTY, "Y" for ciphony, etc. So, in the early R&D stage, "YACKMAN" stood for a voice equipment; "WALLER" for a TTY equipment, "GATLING" for a generator, etc.

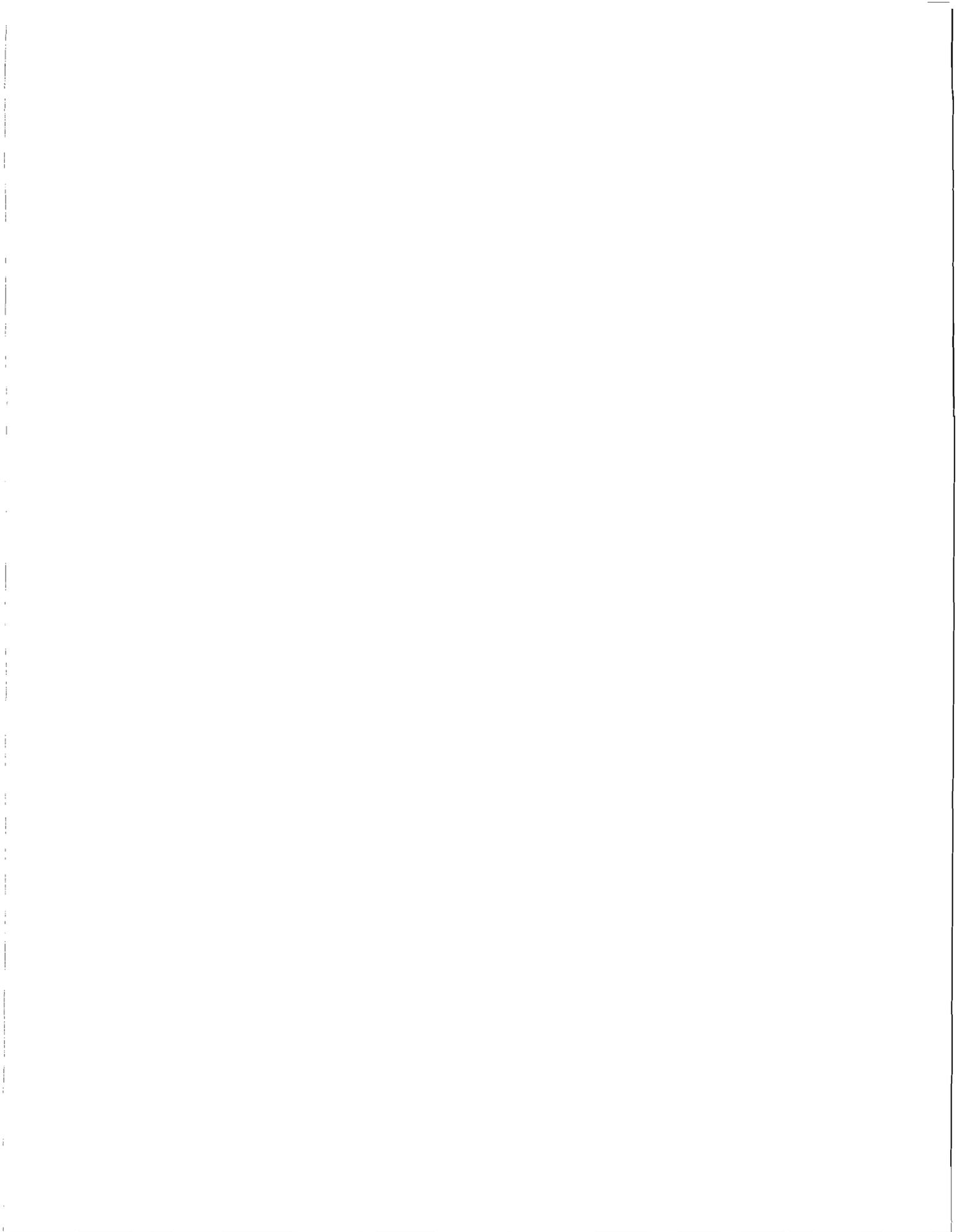
When it looks like a development is going to come to fruition, TSEC nomenclature is assigned, and *suffixes* are added to the basic designators to indicate the stage reached in each model: these can involve experimental models (designated X), development models (designated D), test models (T), pre-production models (P), and finally, with the first full scale production model, no suffix at all.

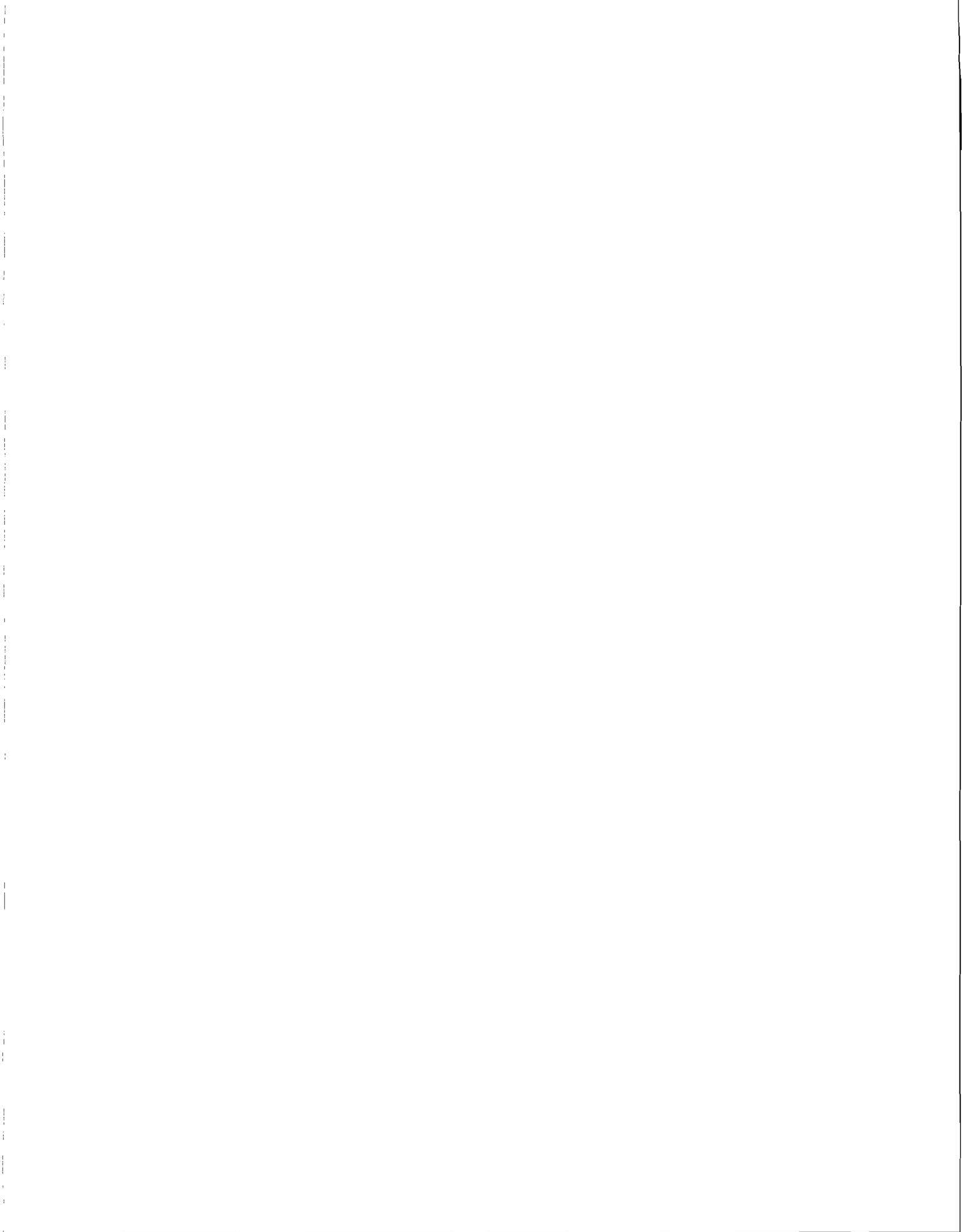
So there could have been versions of the KW-26 successively called: W-; KW-26-X; KW-26-D; KW-26-T; KW-26-P, and the first operational equipment called merely KW-26. But, in fact, when some of the early models come out well enough, some of these stages may be skipped; in fact, most of them were with the KW-26, and it has been increasingly the trend to skip as many as possible to save time and money.

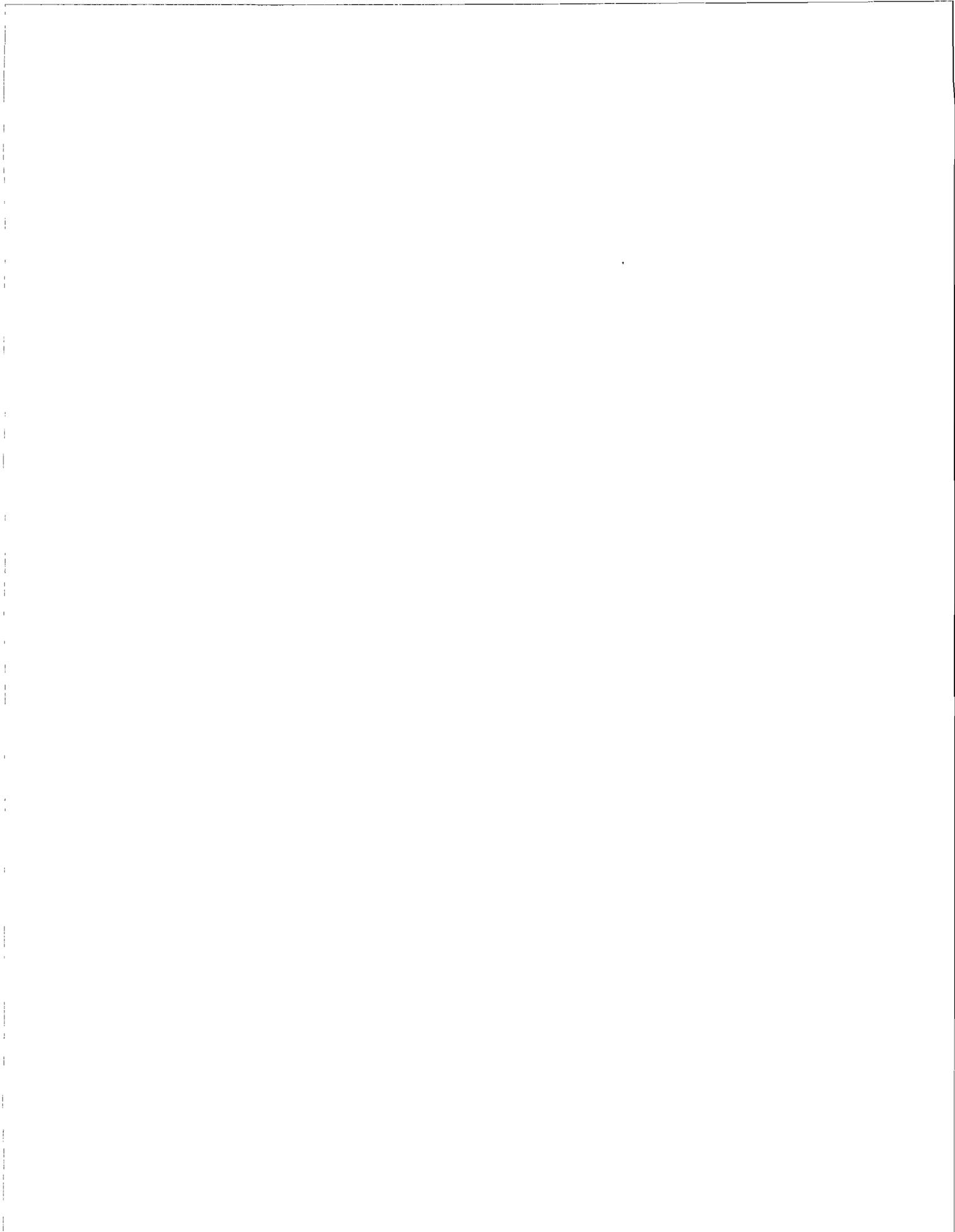
But this tortuous path of nomenclating does not end, even here. *After* the equipment gets into production, more often than not, some modifications need to be made to it and, when this occurs, we need some means of differentiating them, mainly for maintenance and logistical reasons, and the suffixes A, B, C, etc., are assigned. So, in fact, we now have four operational versions of the KW-26: the KW-26-A, the KW-26-B, KW-26-C, and KW-26-D.



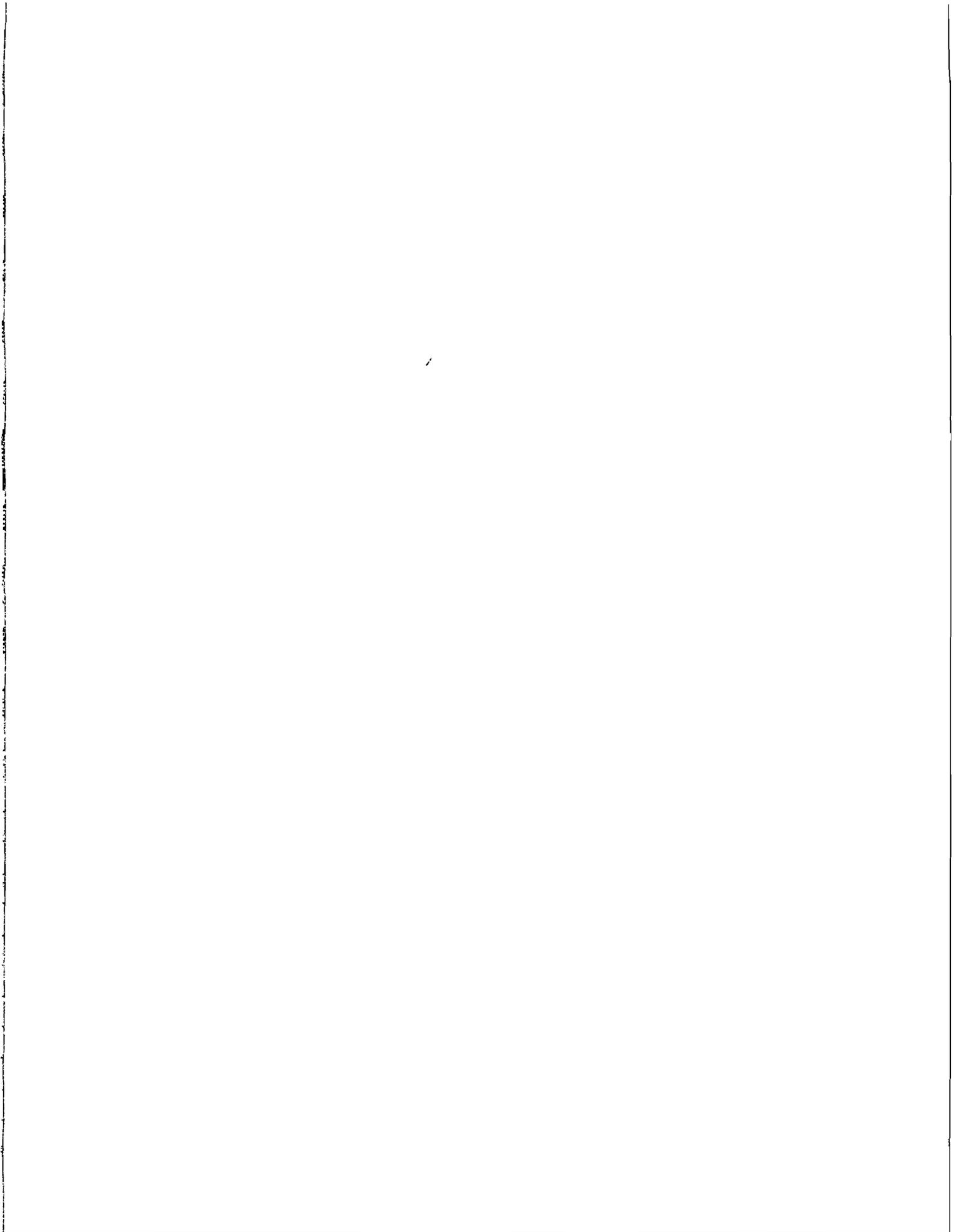


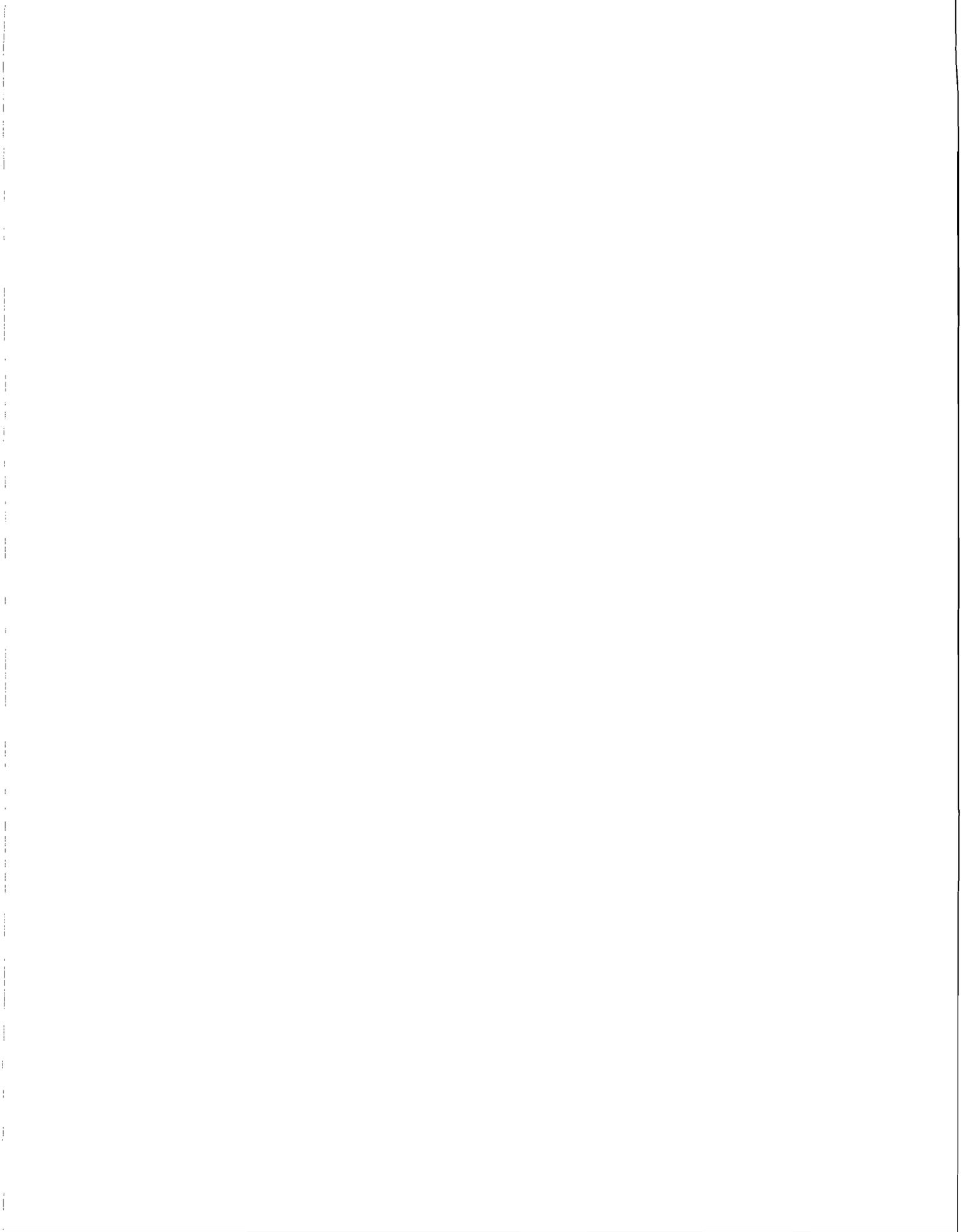


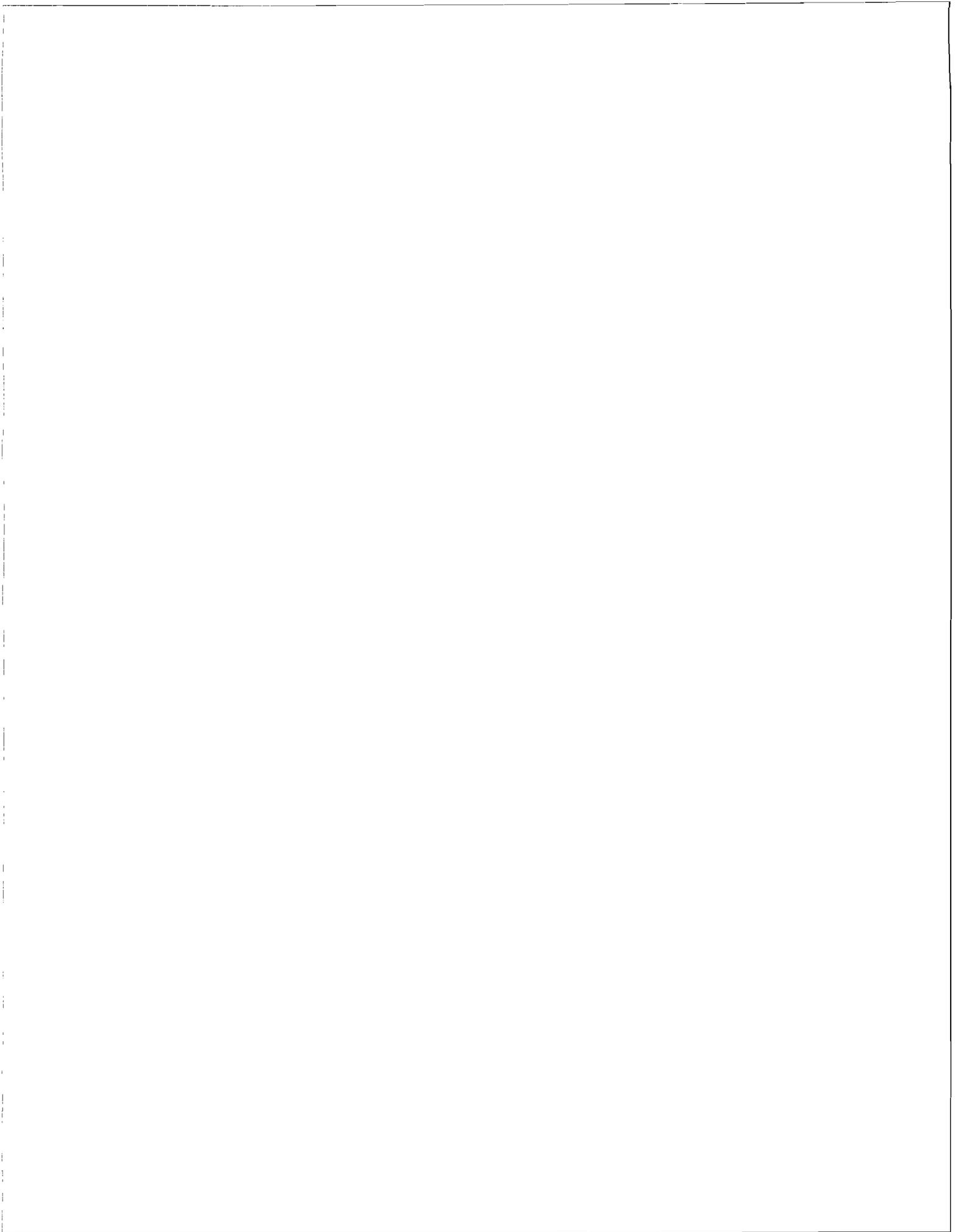


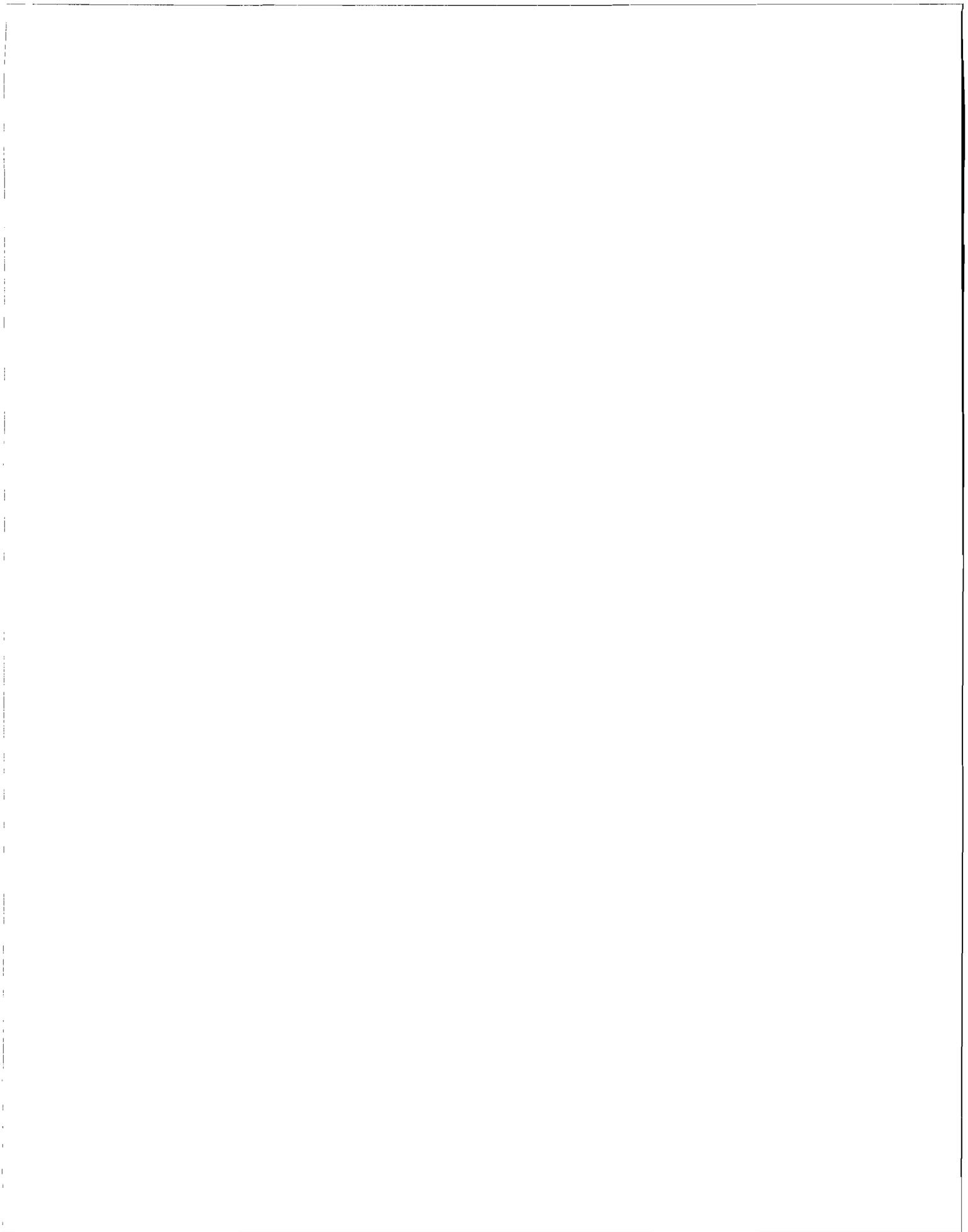


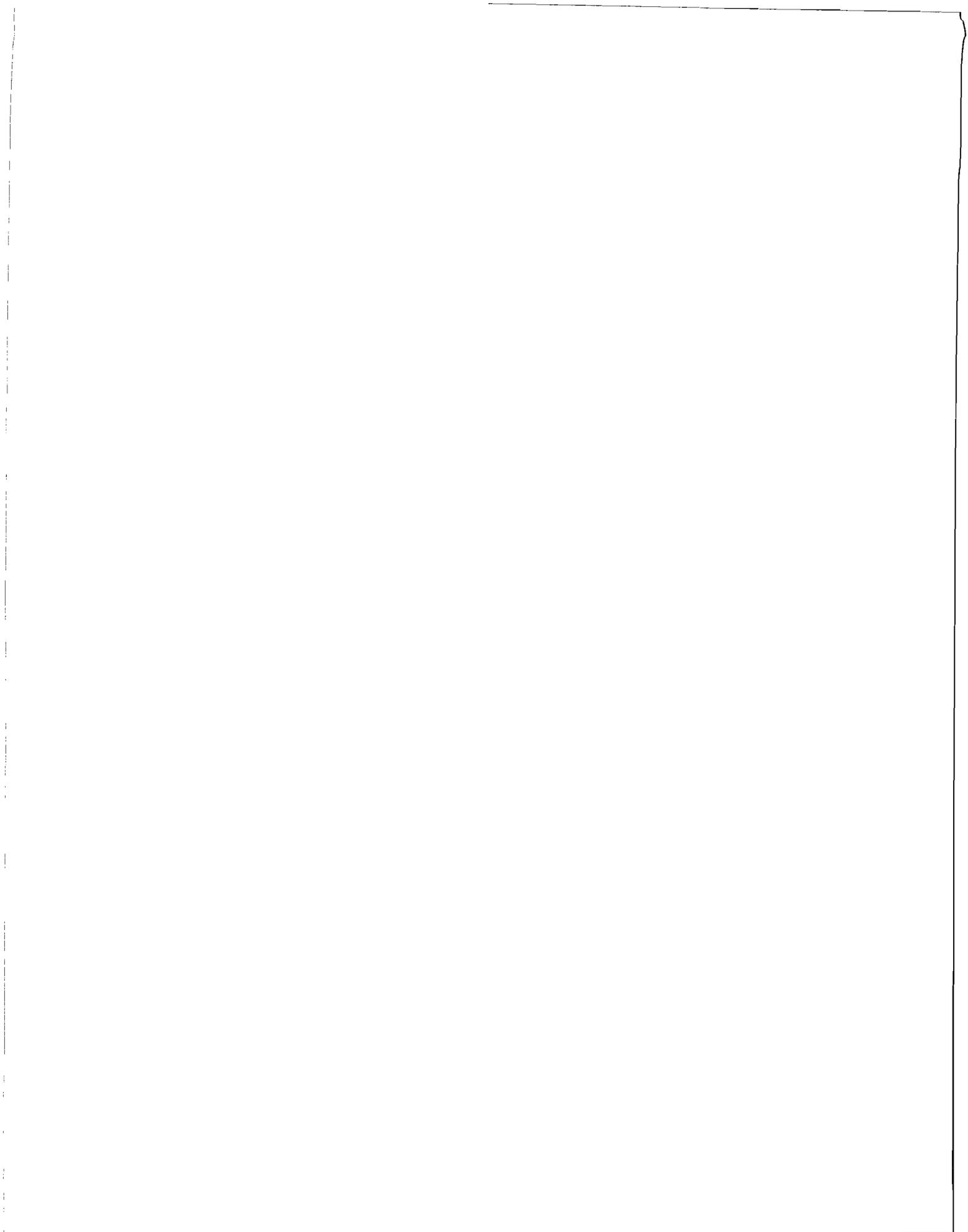


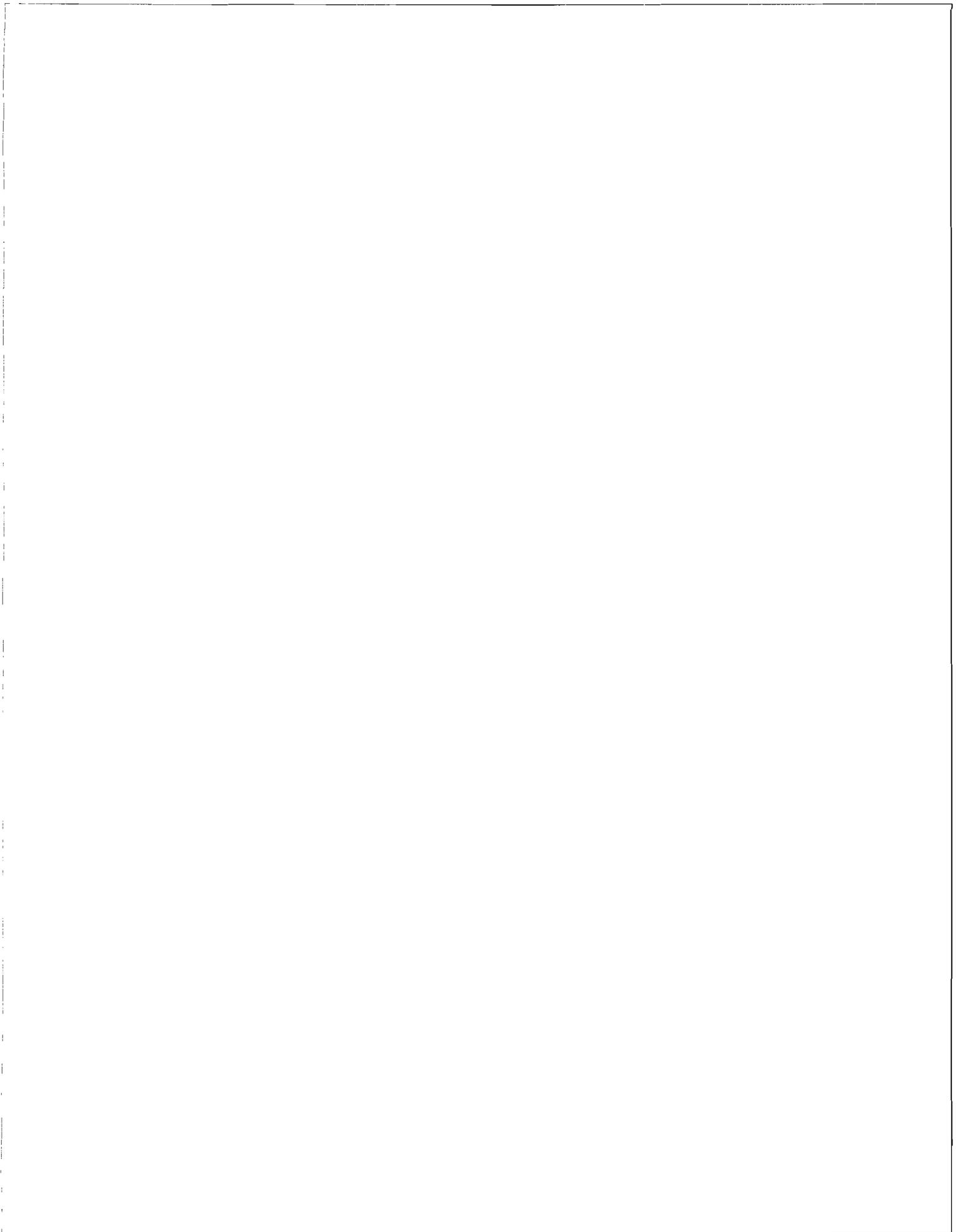


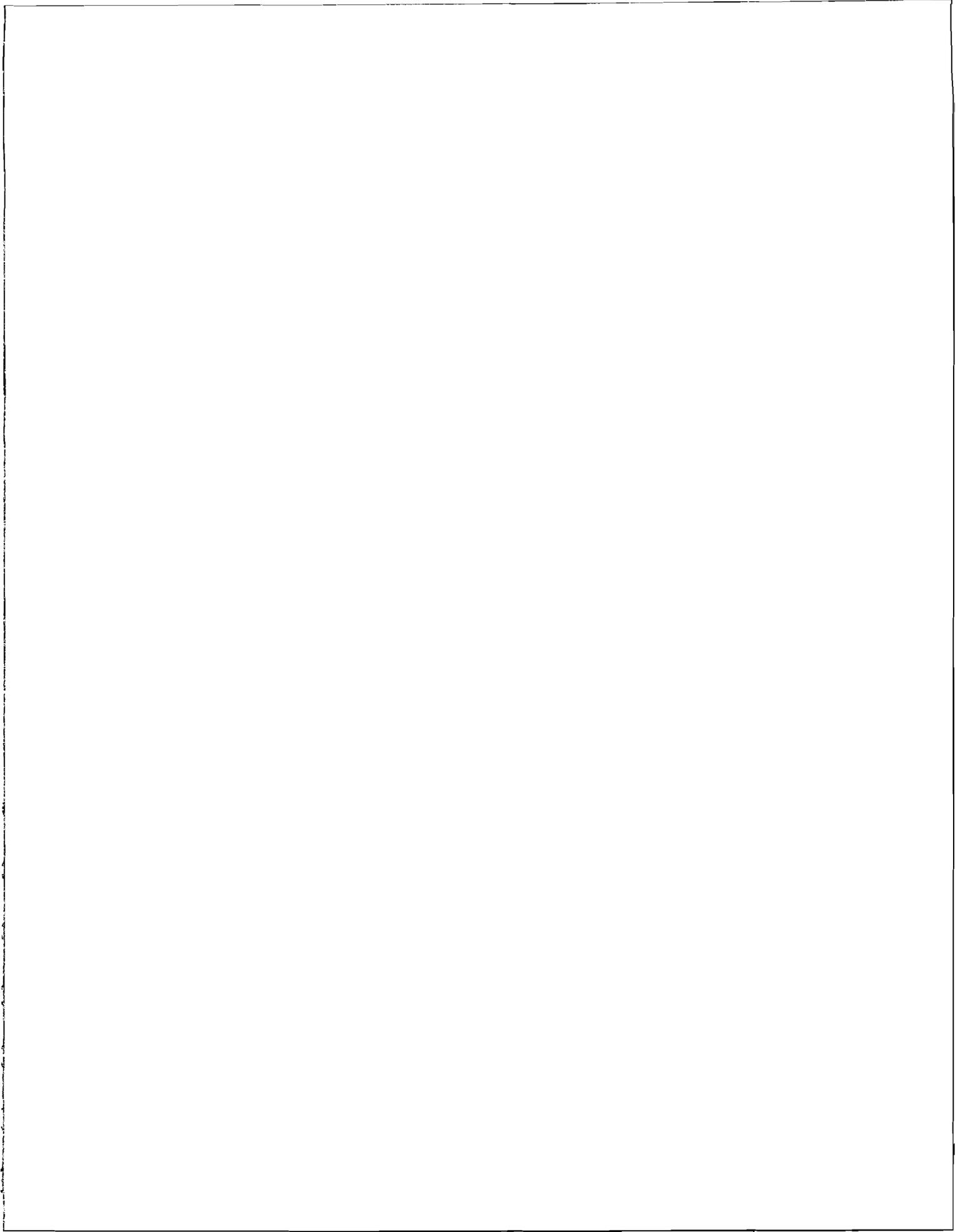


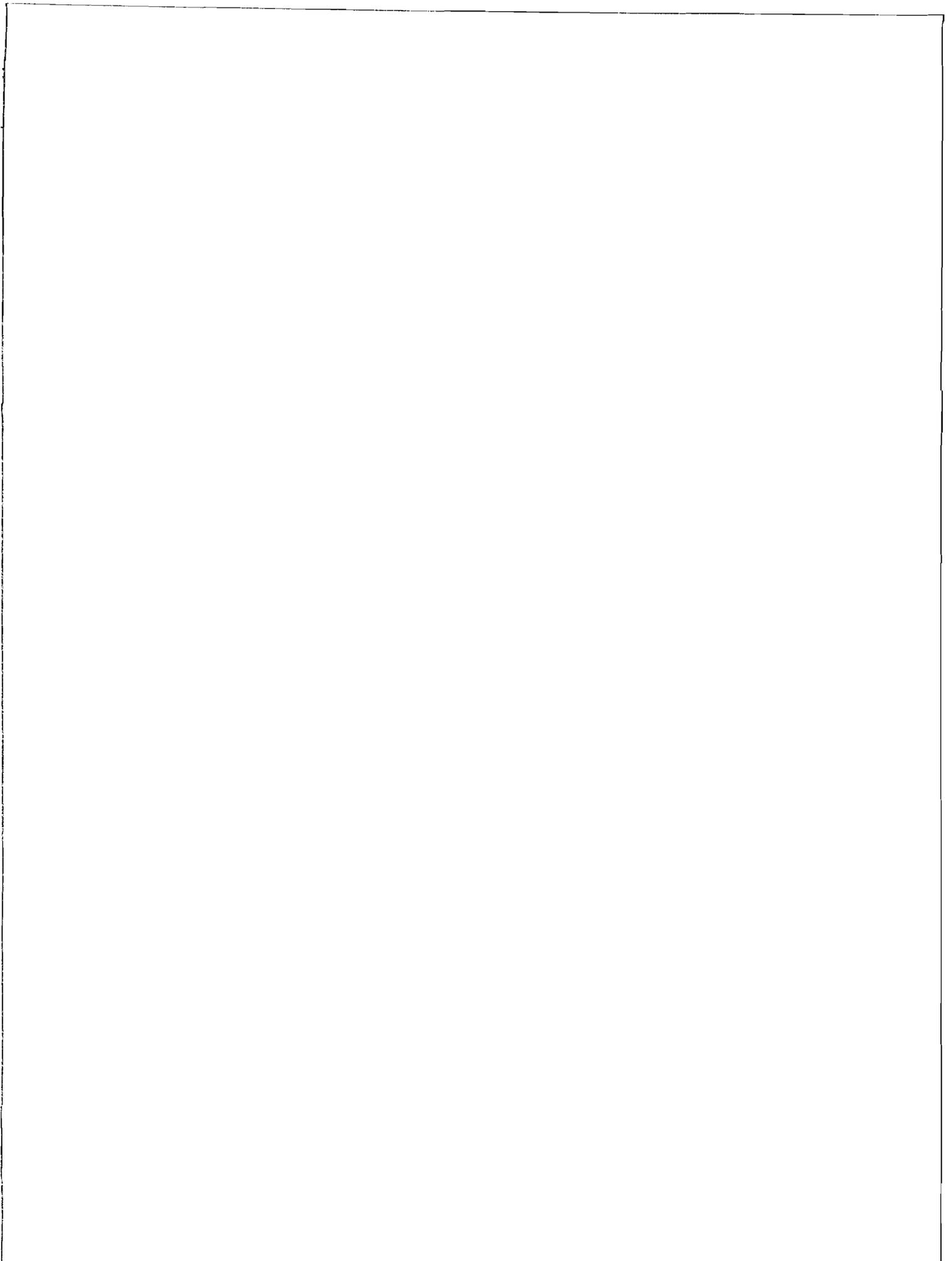














TENTH LECTURE:

TEMPEST

In 1962, an officer assigned to a very small intelligence detachment in Japan was performing the routine duty of inspecting the area around his little cryptocenter. As required he was examining a zone 200 ft. in radius to see if there was any "clandestine technical surveillance". Across the street, perhaps a hundred feet away, was a hospital controlled by the Japanese government. He sauntered past a kind of carport jutting out from one side of the building and, up under the eaves, noticed a peculiar thing—a carefully concealed dipole antenna, horizontally polarized, with wires leading through the solid cinderblock wall to which the carport abutted. He moseyed back to his headquarters, then quickly notified the counter-intelligence people and fired off a report of this "find" to Army Security Agency, who, in turn, notified NSA. He was directed to examine this antenna in detail and perhaps recover it, but although the CIC had attempted to keep the carport under surveillance that night, the antenna had mysteriously disappeared when they checked the next day. Up on the roof of the hospital was a forest of Yagi's, TV-antennas, all pointing towards Tokyo in the normal fashion, except *one*. That one was aimed right at the U.S. cryptocenter.

Why, back in 1954, when the Soviets published a rather comprehensive set of standards for the suppression of radio frequency interference, were those standards much more stringent for their teletypewriters and other communications equipment than for such things as diathermy machines, industrial motors, and the like, even though the teleprinters were much quieter in the first place?

Behind these events and questions lies a very long history beginning with the discovery of a possible threat, the slow recognition of a large number of variations of that threat and, lumbering along a few months or a few years afterwards, a set of countermeasures to reduce or eliminate each new weakness that has been revealed. I am going to devote several hours to this story, because your exposure to this problem may be only peripheral in your other courses, because it has considerable impact on most of our cryptosystems, and because we view it as the most serious technical security problem we currently face in the COMSEC world.

First, let me state the general nature of the problem as briefly as I can, then I will attempt something of a chronology for you. In brief: any time a machine is used to process classified information electrically, the various switches, contacts, relays, and other components in that machine may emit radio frequency or acoustic energy. These emissions, like tiny radio broadcasts, may radiate through free space for considerable distances—a half mile or more in some cases. Or they may be induced on nearby conductors like signal lines, power lines, telephones lines, or water pipes and be conducted along those paths for some distance—and here we may be talking of a mile or more.

When these emissions can be intercepted and recorded, it is frequently possible to analyze them and recover the intelligence that was being processed by the source equipment. The phenomenon affects not only cipher machines but *any* information-processing equipment—teleprinters, duplicating equipment, intercomms, facsimile, computers—you name it. But it has special signifi-

ance for cryptomachines because it may reveal not only the plain text of individual messages being processed, but also that carefully guarded information about the internal machine processes being governed by those precious keys of ours. Thus, conceivably, the machine could be radiating information which could lead to the reconstruction of our key lists—and that is absolutely the worst thing that can happen to us.

Now, let's go back to the beginning. During WW II, the backbone systems for Army and Navy secure TTY communications were one-time tapes and the primitive rotor key generator then called SIGTOT. Bell Telephone rented and sold the military a mixing device called a 131-B2 and this combined with tape or SIGTOT key with plain text to effect encryption. They had one of these mixers working in one of their laboratories and, quite by accident, noted that each time the machine stepped, a spike would appear on an oscilloscope in a distant part of the lab. They examined these spikes more carefully and found, to their real dismay, that they could read the plain text of the message being enciphered by the machine. Bell Telephone was kind enough to give us some of their records of those days, and the memoranda and reports of conferences that ensued after this discovery are fascinating. They had sold the equipment to the military with the assurance that it was secure, but it wasn't. The only thing they could do was to tell the Signal Corps about it, which they did. There they met the charter members of a club of skeptics (still flourishing!) which could not believe that these tiny pips could really be exploited under practical field conditions. They are alleged to have said something like: "Don't you realize there's a war on? We can't bring our cryptographic operations to a screeching halt based on a dubious and esoteric laboratory phenomenon. If this is really dangerous, prove it." The Bell engineers were placed in a building on Varick Street in New York. Across the street and about 80 feet away was Signal Corps' Varick Street cryptocenter. The Engineers recorded signals for about an hour. Three or four hours later, they produced about 75% of the plain text that was being processed—a fast performance, by the way, that has rarely been equalled. (Although, to get ahead of the story for a moment, in some circumstances now-a-days, either radiated or conducted signals can be picked up, amplified, and used to drive a teletypewriter directly thus printing out the compromising information in real time.)

The Signal Corps was more than somewhat shook at this display and directed Bell Labs to explore this phenomenon in depth and provide modifications to the 131-B2 mixer to suppress the danger. In a matter of six months or so, Bell Labs had identified three separate phenomena and three basic suppression measures that might be used. The first two phenomena were the space radiated and conducted signals I have described to you; the third phenomenon was magnetic fields. Maybe you remember from high school physics having to learn about left hand rule of thumb and right hand rule of thumb, and it had to do with the fact that a magnetic field is created around a wire every time current flows. Well, a prime source of radiation in an old-fashioned mixing device is a bank of magnet-actuated relays that open and close to form the elements of teletypewriter characters being processed. The magnetic fields surrounding those magnets expand and collapse each time they operate, so a proper antenna (usually some kind of loop, I think) nearby can detect each operation of each relay and thus recover the characters being processed. The bad thing about magnetic fields is that they exist in various strengths for virtually all the circuitry we use and are extremely difficult to suppress. The good thing about them is that they "attenuate" or decay rapidly. Even strong fields disappear in 30 feet or so, so they comprise a threat only in special circumstances where a hostile intercept activity can get quite close to us.

The three basic suppression measures Bell Labs suggested were:

1. Shielding (for radiation through space and magnetic fields),
2. Filtering (for conducted signals on power lines, signal lines, etc),
3. Masking (for either space radiated or conducted signals, but mostly for space).

The trouble with these solutions, whether used singly or in combination, all stems from the same thing: that is the fact that, quite typically, these compromising emanations may occur over a very large portion of the frequency spectrum, having been seen from near d.c. all the way up to the gigacycle range (and that's a lot of cycles). Furthermore, 5 copies of the same machine may each

exhibit different characteristics, radiating at different frequencies and with different amplitudes. And even the same machine may change from day to day as humidity changes or as contacts become pitted, or as other components age. This means that any shielding used must form an effective barrier against a large variety of signals, and this proves difficult. Similarly, the filter has to be a nearly perfect one and they become big, heavy, and expensive. Furthermore, on signal lines for example, how do you get your legitimate cipher signal through without compromising signals squeezing through with them?

Masking, which is the notion of deliberately creating a lot of ambient electrical noise to override, jam, smear out or otherwise hide the offending signals, has its problems too. It's very difficult to make a masking device which will consistently cover the whole spectrum, and the idea of deliberately generating relatively high amplitude interference does not sit too well with folks like IRAC (The Interdepartmental Radio Advisory Committee) of the Office of Telecommunications (OTP) who don't like the idea of creating herring bone patterns in nearby TV pictures or interrupting legitimate signals like aircraft beacons.

Bell Labs went ahead and modified a mixer, calling it the 131-A1. In it they used both shielding and filtering techniques. Signal Corps took one look at it and turned thumbs down. The trouble was, to contain the offending signals, Bell had to virtually encapsulate the machine. Instead of a modification kit that could be sent to the field, the machines would have to be sent back and rehabilitated. The encapsulation gave problems of heat dissipation, made maintenance extremely difficult, and hampered operations by limiting access to the various controls.

Instead of buying this monster, the Signal Corps people resorted to the only other solution they could think of. They went out and warned commanders of the problem, advised them to control a zone about 100 feet in diameter around their communications center to prevent covert interception, and let it go at that. And the cryptologic community as a whole let it go at that for the next seven years or so. The war ended; most of the people involved went back to civilian life; the files were retired, dispersed, and destroyed. The whole problem was plain forgotten. Then, in 1951, the problem was, for all practical purposes, rediscovered by CIA when they were toying with the same old 131-B2 mixer. They reported having read plain text about a quarter mile down the signal line and asked if we were interested. Of course, we were. Some power line and signal line filters were built and immediately installed on these equipments and they did the job pretty well as far as conducted signals were concerned. Space radiation continued unabated, however, and the first of many "radiation" policies was issued in the form of a letter (AFSA Serial: 000404, Nov. 1953?) to all SIGINT activities requiring them to either:

1. Control a zone 200 feet in all directions around their cryptocenters (the idea of preventing interceptors from getting close enough to detect space radiation easily), or
2. Operate at least 10 TTY devices simultaneously (the idea of masking; putting out such a profusion of signals that interception and analysis would be difficult), or
3. Get a waiver based on operational necessity.

And the SIGINT community conformed as best it could; and general service communicators adopted similar rules in some instances. The 200 feet figure, by the way, was quite arbitrary. It was not based on any empirical evidence that beyond such distance interception was impractical. Rather, it was the biggest security zone we believed the majority of stations could reasonably comply with and we knew that, with instrumentation then available, successful exploitation at that range was a darn sight more difficult than at closer distances and, in some environments not practical at all.

At the same time we were scurrying around trying to cope with the 131-B2 mixer, we thought it would be prudent to examine every other cipher machine we had to see whether the same problem existed. For, way back in the late 40's, Mr. Ryon Page and one of his people were walking past the cryptocenter at Arlington Hall and had heard the rotor machines inside clunking away. He wondered what the effect would be on the security of those systems if someone were able to determine which rotors or how many rotors were stepping during a typical encryption process. In due course, some

assessments were made on what the effect would be. The assessments concluded that it would be bad, and they were filed away for future reference. Now, it appeared that there might be a way for an interceptor to recover this kind of data. So, painstakingly, we began looking at our cryptographic inventory. Everything tested radiated and radiated rather prolifically. In examining the rotor machines, it was noted the voltage on their power lines tended to fluctuate as a function of the numbers of rotors moving, and so a fourth phenomenon, called power line modulation, was discovered through which it was possible to correlate tiny surges and drops in power with rotor motion and certain other machine functions.

Progress in examining the machines and developing suppression measures was very slow. In those days, S2 did not have any people or facilities to work on this problem; no fancy radio receivers or recording devices, no big screen rooms and other laboratory aids, and such things as we obtained we begged from the SIGINT people at Ft. Meade. In due course, they got overloaded, and they could no longer divert their SIGINT resources to our COMSEC problems. So R&D began to pick up a share of the burden, and we began to build up a capability in S2. The Services were called in, and a rudimentary joint program for investigative and corrective action got underway. The Navy, particularly, brought considerable resources to bear on the problem.

By 1955, a number of possible techniques for suppressing the phenomena had been tried: filtering techniques were refined somewhat; teletypewriter devices were modified so that all the relays operated at once so that only a single spike was produced with each character, instead of five smaller spikes representing each baud—but the size of the spike changed with each character produced and the analysts could still read it quickly. A "balanced" 10-wire system was tried which would cause each radiated signal to appear identical, but to achieve and maintain such balance proved impractical. Hydraulic techniques were tried to get away from electricity, but were abandoned as too cumbersome; experiments were made with different types of batteries and motor generators to lick the power line problem—none too successfully. The business of discovering new TEMPEST threats, of refining techniques and instrumentation for detecting, recording, and analyzing these signals progressed more swiftly than the art of suppressing them. With each new trick reported to the bosses for extracting intelligence from cryptomachines and their ancillaries, the engineers and analysts got the complaint: "Why don't you guys stop going onward and upward, and try going downward and backward for a while—cure a few of the ills we already know about. Instead of finding endless new ones." I guess it's a characteristic of our business that the attack is more exciting than the defense. There's something more glamorous, perhaps, about finding a way to read one of these signals a thousand miles away than to go through the plain drudgery and hard work necessary to suppress that whacking great spike first seen in 1943.

At any rate, when they turned over the next rock, they found the acoustical problem under it. Phenomenon #5. Of course, you will recall Mr. Page and his people speculating about it way back in 1949 or so, but since the electromagnetic phenomena were so much more prevalent and seemed to go so much farther, it was some years before we got around to a hard look at what sonic and ultrasonic emissions from mechanical and electromechanical machines might have in store.

We found that most acoustical emanations are difficult or impossible to exploit as soon as you place your microphonic device outside of the room in which the source equipment is located: you need a direct shot at the target machine; a piece of paper inserted between, say an offending keyboard, and the pickup device is usually enough to prevent sufficiently accurate recordings to permit exploitation. Shotgun microphones—the kind used to pick up a quarterback's signals in a huddle—and large parabolic antennas are effective at hundreds of feet if, again, you can see the equipment. But in general, the acoustical threat is confined to those installations where the covert interceptor has been able to get some kind of microphone in the same room with your information-processing device—some kind of microphone like an ordinary telephone that has been bugged or left off the hook. One interesting discovery was that, when the room is "soundproofed" with ordinary acoustical tiles, the job of exploitation is easier because the soundproofing cuts down reflected and reverberating sound, and thus provides cleaner signals. A disturbing discovery was that ordinary microphones, probably planted for the purpose of picking up conversations in a cryptocenter, could detect

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machine sounds with enough fidelity to permit exploitation. And such microphones were discovered in [redacted]

The example of an acoustical intercept I just showed you is from an actual test of the little keyboard of the KL-15. You will note that each individual key produces a unique "signature". Since (before it died) the KL-15 was expected to be used in conjunction with telephonic communications, this test was made by placing the machine a few feet from a gray phone handset at Ft. Meade and making the recording in the laboratory at Nebraska Avenue from another handset. So that's really a recording taken at a range of about 25 miles, and the signals were encrypted and decrypted in the gray phone system, to boot.

The last but not least of the TEMPEST phenomena which concerns us is referred to as cipher signal modulation or, more accurately, as cipher signal anomalies. An anomaly, as you may know, is a peculiarity or variation from the expected norm. The theory is this: suppose, when a cryptosystem is hooked to a radio transmitter for on-line operation, compromising radiation or conducted signals get to the transmitter right along with the cipher text and, instead of just sending the cipher text, the transmitter picks up the little compromising emissions as well and sends them out full blast. They would then "hitchhike" on the cipher transmission, modulating the carrier, and would theoretically travel as far as the cipher text does. Alternatively, suppose the compromising emanations cause some tiny variations or irregularities in the cipher characters themselves, "modulate" them, change their shape or timing or amplitude? Then, possibly, anyone intercepting the cipher text (and anyone can) can examine the structure of the cipher signals minutely (perhaps by displaying and photographing them on the face of an oscilloscope) and correlate these irregularities or anomalies with the plain text that was being processed way back at the source of the transmission. This process is called "fine structure analysis". Clearly, if this phenomenon proves to be at all prevalent in our system, its implications for COMSEC are profound. No longer are we talking about signals which can, at best, be exploited at perhaps a mile or two away and, more likely, at a few hundred feet or less. No longer does the hostile interceptor have to engage in what is really an extremely difficult and often dangerous business, i.e., getting covertly established close to our installations, working with equipment that must be fairly small and portable so that his receivers are unlikely to be ultra-sensitive, and his recording devices far less than ideal. Rather, he may sit home in a full-scale laboratory with the most sophisticated equipment he can assemble and, with plenty of time and no danger carry out his attack. But, so far, we seem to be all right. For several years, we have had SIGINT stations collecting samples of U.S. cipher transmissions containing possible anomalies and forwarding them here for detailed examination. We have no proven case of operational traffic jeopardized this way.

I believe we've talked enough about the difficulties we face.

In late 1956, the Navy Research Laboratory, which had been working on the problem of suppressing compromising emanations for some years, came up with the first big breakthrough in a suppression technique. The device they produced was called the NRL Keyer, and it was highly successful. After being confronted with the shortcomings of shields and filters and maskers, they said, "Can we find a way of eliminating these offending signals at their source? Instead of trying to bottle up, filter out, shield, mask, or encapsulate these signals, why not reduce their amplitudes so much that they just can't go very far in the first place? Can we make these critical components operate at one or two volts instead of 60 or 120, and use power measured in microamps instead of milliamps?" They could, and did. NSA quickly adopted this low-level keying technique and immediately produced several hundred one-time tape mixers using this circuitry, together with some nominal shielding and filtering. The equipment was tested, and components that previously radiated signals which were theoretically exploitable at a half mile or so could no longer be

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detected at all beyond 20 feet. The next equipment built, the KW-26, and every subsequent crypto-equipment produced by this Agency contained these circuits, and a great stride had been made.

But we weren't out of the woods yet: the communicators insisted that the reduced voltages would give reduced reliability in their equipments, and that while satisfactory operation could be demonstrated in a simple setup with the crypto-machine and its input-output devices located close by, if the ancillaries were placed at some distance ("remoted" they call it), or if a multiplicity of ancillaries had to be operated simultaneously from a single keyer, or if the low level signals had to be patched through various switchboard arrangements, operation would be unsatisfactory. The upshot was that in the KW-26 and a number of other NSA machines, an "option" was provided—so that either high-level radiating signals could be used or low-level keying adopted. In the end, almost all of the installations were made without full suppression. Even the CRITICOM network, the key intelligence reporting system over which NSA exercises the most technical and operational control, was engineered without full-scale, low-level keying.

The next difficulty we found in the corrective action program was the great difference in cost and efficiency between developing new relatively clean equipment by incorporating good suppression features in the basic design, and in retrofitting the tens of thousands of equipments—particularly the ancillaries such as teletypewriters—which we do not build ourselves but, rather, acquire from commercial sources. For, in addition to the need for low-level keyers, some shielding and filtering is still normally required; circuits have to be laid out very carefully with as much separation or isolation as possible between those which process plain text and those which lead to the outside world—this is the concept known as Red/Black separation, with the red circuits being those carrying classified plain text, and the other circuits being black. Finally, grounding had to be very carefully arranged, with all the red circuits sharing a common ground and with that ground isolated from any others. To accomplish this task in an already established installation is extremely difficult and costly, and I'll talk about it in more detail later when I cover the basic plans, policies, standards, and criteria which have now been adopted.

By 1958, we had enough knowledge of the problem, possible solutions in hand, and organizations embroiled to make it possible to develop some broad policies with respect to TEMPEST. The MCEB (Military Communications Electronics Board) operating under the JCS, formulated and adopted such policy—called a Joint policy because all the Services subscribed to it. It established some important points:

1. As an *objective*, the Military would not use equipment to process classified information if it radiated beyond the normal limits of physical control around a typical installation.
2. *Fifty feet* was established as the normal limit of control. The choice of this figure was somewhat arbitrary; but *some* figures had to be chosen since equipment designers needed to have some upper limit of acceptable radiation to work against.
3. NAG-1, a document produced by S2, was accepted as the standard of measurement that designers and testers were to use to determine whether the fifty-foot limit was met. This document specifies the kinds of measurements to be made, the sensitivity of the measuring instruments to be used, the specific procedures to be followed in making measurements, and the heart of the document sets forth a series of *curves* against which the equipment tester must compare his results: if these curves are exceeded, radiated signals (or conducted signals, etc.) can be expected to be detectable *beyond* 50 feet, and added suppression is necessary.
4. The classification of various aspects of the TEMPEST problem was specified.

Documents like these are important. It was more than an assembly of duck-billed platitudes; it set the course that the Military would follow, and laid the groundwork for more detailed policies which would eventually be adopted nationally. It had weaknesses, of course. It said nothing about *money*, for example; and the best intentions are meaningless without budgetary action to support them. And it set no time frame for accomplishing the objective. And it provided no priorities for action, or factors to be used in determining which equipments, systems, and installations were to be made to conform first.

The next year, 1959, the policy was adopted by the Canadians and UK, and thus became a Combined policy. This gave it a little more status, and assured that there would be a consistent planning in systems used for Combined communications. In that same year, the first National COMSEC Plan was written. In it, there was a section dealing with compromising emanations. This document was the first attempt to establish some specific responsibilities among various agencies of Government with respect to TEMPEST, and to lay out an orderly program of investigative and corrective action. Based on their capabilities and interest, six organizations were identified to carry out the bulk of the work. These were ourselves, Navy, Army, Air Force, CIA, and State. The plan also called for some central coordinating body to help manage the overall effort. It was also in this plan that, for the first time, there were really explicit statements made indicating that the TEMPEST problem was not confined to communications security equipment and its ancillaries, that it extended to any equipment used to process classified information, including computers.

And so, it was in about this time frame that the word began to leak out to people outside the COMSEC and SIGINT fields, to other agencies of government, and to the manufacturing world.

You may remember from your briefings on the overall organization of this Agency, that there is something called the U.S. Communications Security Board, and that very broad policy direction for all COMSEC matters in the government stems from the Board. It consists of a chairman from the Dept. of Defense through whom the Director, NSA reports to the Secretary of Defense, and members from NSA, Army, Navy, Air Force, State, CIA, FBI, AEC, Treasury and Transportation. This Board meets irregularly, it does its business mainly by circulating proposed policy papers among its members and having them vote for adoption. The USCSB met in 1960 to contemplate this TEMPEST problem, and established its first and only permanent committee to cope with it. This committee is referred to as SCOCE (Special Committee on Compromising Emanations) and has, to date, always been chaired by a member of the S Organization.

The ink was hardly dry on the committee's charter before it got up to its ears in difficulty. The counterpart of USCSB in the intelligence world is called USIB—the U.S. Intelligence Board. Unlike USCSB, it meets regularly and has a structure of permanent committees to work on various aspects of their business. One part of their business, of course, consists of the rapid processing, by computer techniques, of a great deal of intelligence, and they had been contemplating the adoption of some standardized input-output devices of which the archetype is an automatic electric typewriter called *Flexowriter* which can type, punch tapes or cards, and produce page copy, and which is a very strong radiator. In a rare action, the Intelligence Board appealed to the COMSEC Board for policy direction regarding the use of these devices and, of course, this was immediately turned over to the fledgling Special Committee. The committee arranged to have some Flexowriters and similar equipments tested. They were found, as a class, to be the strongest emitters of space radiation of any equipment in wide use for the processing of classified information. While, as I have mentioned, typical unsuppressed teletypewriters and mixers are ordinarily quite difficult to exploit much beyond 200 feet through free space, actual field tests to Flexowriters showed them to be readable as far out as 3,200 feet and, typically, at more than 1000 feet, even when they were operated in a very noisy electrical environment.

One such test was conducted at the Naval Security Station. (By the way, in case I haven't mentioned this already, the S Organization was located at the Naval Security Station, Washington D.C. until May 1968 when we moved here to Ft. Meade.) Mobile test equipment had been acquired, including a rolling laboratory which we refer to as "the Van". In S3, a device called *Justowriter* was being used to set up maintenance manuals. Our van started out close to the building and gathered in a great potpourri of signals emitting from the tape factory and the dozens of the machines operating in S3. As they moved out, most of the signals began to fade. But not the Justowriter. By the time they got out to the gas station on the far side of the parking lot—that's about 600 feet—most of the other signals had disappeared, but they could still read the Justowriter. They estimated that the signals were strong enough to have continued out as far as American University grounds three blocks away. (The solution in this case, was to install a shielded enclosure—a subject I will cover subsequently.)

In any event, the Committee submitted a series of recommendations to the USCSB which subsequently became known as the *Flexowriter Policy*. The Board adopted it and it upset everybody. Here's why: as the first point, the Committee recommended that the existing Flexowriters not be used to process classified information at all in any overseas environment; that it be limited to the processing of CONFIDENTIAL information in the United States, and then only if a 400-foot security zone could be maintained around it. Exceptions could be made if the equipment could be placed in an approved shielded enclosure, or as usual, if waivers based on operational necessity were granted by the heads of the departments and agencies concerned.

The Committee also recommended that both a "quick-fix" program and a long-range, corrective action program be carried out. It was recommended that the Navy be made Executive Agent to develop a new equipment which would meet the standards of NAG-1 and, grudgingly, DDR&E gave Navy some funds (about a quarter of what they asked for) to carry out that development. Meanwhile, manufacturers were coaxed to develop some interim suppression measures for their product lines, and the Committee published two lists: one containing equipments which were forbidden, the other specifying acceptable interim devices. This policy is still in force; but most users have been unable to afford the fixes, and have chosen to cease operations altogether, e.g., CIA, or to operate under waivers on a calculated risk basis, e.g., most SIGINT sites.

While the Committee was still reeling from the repercussions and recriminations for having sponsored an onerous and impractical policy which made it more difficult for operational people to do their job, it grasped an even thornier nettle. It undertook to take the old toothless Joint and Combined policies and convert them into a strong National policy which:

1. Would be binding on all departments and agencies of government, not just the military.
2. Would establish NAG-1 as a standard of acceptance for future government procurement of hardware (NAG-1, by the way, was converted to *Federal Standard*. (FS-222) to facilitate its wide distribution and use.)
3. Would establish a deadline for eliminating unsuppressed equipment from government inventories.

By now the governmental effort had changed from a haphazard, halting set of uncoordinated activities mainly aimed at cryptologic problems, to a multi-million dollar program aimed at the full range of information-processing equipment we use. Symposia had been held in Industrial forums to educate manufacturers about the nature of the problem and the Government's intentions to correct it. Work had been parcelled out to different agencies according to their areas of prime interest and competence; the SIGINT community had become interested in possibilities for gathering intelligence through TEMPEST exploitation. It, nonetheless, took the Committee two full years to complete the new National policy and coordinate it with some 22 different agencies. Before it could have any real effect it had to be *implemented*. The implementing directive—5200.19—was signed by Secretary McNamara in December, 1964. Bureaucracy is wonderful. Before its specific provisions could be carried out, the various departments and agencies had to implement the implementing directive within their own organizations. These implementing documents began dribbling in throughout 1965, and it is my sad duty to report that NSA's own implementation did not take effect until June, 1966.

All this makes the picture seem more gloomy than it is. These implementing documents are, in the final analysis, formalities. The fact of the matter is that most organizations, our own included, have been carrying out the intent of these policies to the best of our technical and budgetary abilities for some years.

While all this was going on in the policy field, much was happening in the technical area. First, let me cover the matter of shielded enclosures. To do so, I have to go back to about 1956 when the National Security Council got aroused over the irritating fact that various counter-intelligence people, particularly in the Department of State, kept stumbling across hidden microphones in their residences and offices overseas. They created a Technical Surveillance Countermeasures Committee under the Chairmanship of State and with the Services, FBI, CIA, and NSA also represented. This group was charged with finding out all they could about these listening devices,

and developing a program to counter them. In the space of a few years, they assembled information showing that nearly 500 microphones had been discovered in U.S. installations; all of them overseas, 90% of those behind the [redacted]. They examined a large number of possible countermeasures, including special probes and search techniques, electronic devices to locate microphones buried in walls, and what-have-you. Each June, in their report to the NSC, they would dutifully confess that the state-of-the-art of hiding surveillance devices exceeded our ability to find them. About the only way to be sure an [redacted] was "clean" would be to take it apart inch-by-inch which we couldn't afford, and which might prove fruitless anyhow, since host-country labor had to be used to put it back together again. (Incidentally, years later, we began to think we had darned well better be able to afford something close to it, for we found things that had been undetected in a dozen previous inspections.)

The notion of building a complete, sound-proof, inspectable room-within-a-room evolved to provide a secure conference area for [redacted] and intelligence personnel. During these years, NSA's main interest in and input to the committee had to do with the sanctity of cryptocenters in these vulnerable overseas installations, and we campaigned for rooms that would be not only sound-proof but proof against compromising electromagnetic emanations as well. [redacted] developed a conference room made of plastic which was dubbed the "fish-bowl" and some of them are in use behind the [redacted] now. CIA made the first enclosure which was both "sound-proof" and electrically shielded. This enclosure went over like—and apparently weighed about as much as—a lead balloon. It was nicknamed the "Meat Locker" and the consensus was that nobody would consent to work in such a steel box, that they needed windows and drapes or they'd get claustrophobia or something. Ironically, though, it turned out that some of the people who were against this technique for aesthetic reasons spent their days in sub-sub basement areas with cinder-block walls and no windows within 50 yards.

The really attractive thing about the enclosures, from the security point of view, was the fact that they provided not only the best means, but the only means we had come across to provide really complete TEMPEST protection in those environments where a large-scale intercept effort could be mounted at close range. So, despite aesthetic problems, and weight, and cost, and maintenance, and enormous difficulties in installation, we campaigned very strongly for their use in what we called "critical" locations, with [redacted] at the top of the list.

So again, in the matter of Standards, NSA took the lead, publishing two specifications (65-5 and 65-6) one describing "fully" shielded enclosures with both RF and acoustic protection; the other describing a cheaper enclosure providing RF protection only. And by threats, pleas, "proofs" and persuasion, we convinced the [redacted] CIA, and the Services, to procure a handful of these expensive, unwieldy screen rooms for installation in their most vulnerable facilities. One of the first, thank goodness, went into [redacted]—in fact, two of them; one for the [redacted] code room as they call it, and one for the cryptocenter used by the [redacted]. So, when highest levels of government required us to produce damage reports on the microphones finds there, we were able with straight faces and good conscience to report that, in our best judgment, cryptographic operations were immune from exploitation—the fully shielded enclosures—were in place.

But none of us was claiming that this suppression measure was suitable for any wide-scale application—it's just too cramped, inflexible, and expensive. We have managed to have them installed not only in overseas installations where we are physically exposed but also in a few locations here at home where the information being processed is of unusual sensitivity. Thus, the [redacted] acquired more than 50 of them to house computers and their ancillaries where a heavy volume of restricted Data must be processed; we have one here in S3 to protect most of our key and code generation equipment—a \$134,000 investment, by the way—which you may see when you tour our production facilities. The Navy has one of comparable size at the Naval Security Station for its computers. (But they have the door open most of the time.) At Operations Building No. 1, on the other hand, we don't have one—instead, we use careful environmental controls, inspecting the whole area around the Operations Building periodically, and using mobile equipment to examine the actual radiation detectable in the area.

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In about 1962, two more related aspects of the TEMPEST problem began to be fully recognized. First, there was the growing recognition of the inadequacies of suppression effort which were being made piece-meal, one equipment at a time, without relating that equipment to the complex of ancillaries and wiring in which it might work. We called this the "system" problem. We needed a way to test, evaluate, and suppress overall secure communications complexes, because radiation and conduction difficulties stem not only from the inherent characteristics of individual pieces of machinery but also from the way they are connected to other machines—the proximity and conductivity and grounding arrangements of all the associated wiring often determined whether a system as a whole was safe. And so, one of the first systems that we tried to evaluate in this way was the COMLOGNET system of the Army. This system, using the KG-13, was intended principally for handling logistics data and involved a number of switches, and data transceivers, and information storage units, and control consoles. Using the sharpest COMSEC teeth we have, our authority for reviewing and approving cryptoprinciples, and their associated rules, regulations, and procedures of use, we insisted that the system as a whole be made safe from the TEMPEST point of view before we would authorize traffic of all classifications to be processed. This brought enough pressure to bear on the system designers for them to set up a prototype complex at Ft. Monmouth and test the whole thing on the spot. They found and corrected a number of weaknesses before the "system" approval was given. A second means we have adopted, in the case of smaller systems, like a KW-7 being used with a teletypewriter and a transmitter distributor, is to pick a relatively small number of most likely configurations to be used and test each as a package. We clean up these basic packages as much as is needed and then approve them. If a user wants to use some less common arrangement of ancillaries, he must first test it. So, in the case of KW-7, we took the three most common teleprinters—the MOD-28 line of Teletype Corporation, the Kleinschmidt (an Army favorite), and the MITE teleprinter; authorized the use of any of these three combinations and provided the specific installation instructions necessary to assure that they would be radiation-free when used. We did the same thing with the little KY-8, this time listing "approved" radio sets with which it could be safely used.

Adequate systems testing for the larger complexes continues to be a problem—one with which S4, S2, DCA, and the Special Committee are all occupied.

The second and related problem that reared its head in about 1962 is the matter of RED/BLACK separation that I mentioned. Over the years, it had become increasingly evident that rather specific and detailed standards, materials, and procedures had to be used in laying out or modifying an installation if TEMPEST problems were to be avoided, and the larger the installation, the more difficult proper installation became—with switching centers perhaps the most difficult case of all. For some years, NSA has been making a really hard effort to get other organizations to display initiative and commit resources to the TEMPEST problem. We simply could not do it all ourselves. So we were pleased to cooperate with DCA when it decided to tackle the question of installation standards and criteria for the Defense Communications System (DCS). It was needed for all three Services; the Services, in fact, actually operate DCS. Virtually every strategic Department of Defense circuit is involved—more than 50,000 in all. DCA felt that this system would clearly be unmanageable unless the Services could standardize some of their equipment, communications procedures, signalling techniques, and the like. General Starbird, who directed DCA, was also convinced that TEMPEST is a serious problem, and desired the Services to use a common approach in DCS installations with respect to that problem. Thus, DCA began to write a very large installation standard comprising a number of volumes, and laying out in great detail how various circuits and equipments were to be installed. NSA personnel assisted in the technical inputs to this document called DCA Circular 175-6A. A Joint Study Group was formed under DCA chairmanship to coordinate the installation problem as well as a number of other TEMPEST tasks affecting the Defense Communications System and the National Communications System (NCS) which interconnects strategic civil organizations along with the Defense Department. In developing the installation standards, the study group and DCA took a rather hard line, and specified tough requirements for isolating all the RED circuits, equipments, and areas from the BLACK ones, i.e., assuring

physical and electrical separation between those circuits carrying classified information in the clear, and those carrying only unclassified information (like cipher signals, control signals, power, and ordinary telephone lines). In addition to shielding and filtering, this called for the use of conduits and often, in existing installations, drastic rearrangement of all the equipment and wiring was involved.

You will remember that the Department of Defense had directed that extensive TEMPEST corrective action be taken. I said that the Directive specified NAG-1 (FS-222) as a standard of acceptance for new equipment. It also mentioned a number of other documents as being applicable, and particularly, this very same DCA Circular I've just been describing.

As this whole program gathered steam, the monetary implications began to look staggering; the capability of the government accomplishing *all* the corrective action implied in a reasonable time seemed doubtful: furthermore, we were beginning to see that there were subtle inter-relationships between different kinds of countermeasures; and that some of these countermeasures, in particular situations, might be quite superfluous when some of the other countermeasures were rigidly applied. Remember, by now we had been telling people to shield, to filter, to place things in conduit, to ground properly, to separate circuits, to use low-level keying, to provide security zones and sometimes, to use shielded enclosures. It took us a while to realize some fairly obvious things, for example, if you have done a very good job of suppressing space radiation, you may not need very much filtering of the signal line because there's no signal to induce itself on it; or you may not need to put that line in conduit for the same reason. If you have put a line in conduit, which is a kind of shielding, then perhaps you don't have to separate it very far from other lines because the conduit itself has achieved the isolation you seek. And so forth. We had already realized that some installations, inherently, have fewer TEMPEST problems than others. The interception of space radiation from an equipment located in a missile silo or SAC's underground command center does not seem practicable; so perhaps the expensive space radiation suppressions ought not be applied there. Similarly, the suppression measures necessary in an airborne platform or in a ship at sea are quite different from those needed in a communications center in Germany.

The upshot was that, in 1965, NSA undertook to examine all the standards and techniques of suppression that had been published, to relate them to one another, and to provide some guidelines on how the security *intent* of the "national policy" and its implementing directives could be met through a judicious and *selective* application of the various suppression measures as a function of installation, environment, traffic sensitivity, and equipment being used. These guidelines were published as NSA Circular 90-9 and have been extremely well received.

In December 1970, the U.S. TEMPEST community introduced new TEMPEST laboratory test standards for non-cryptographic equipments. Test procedures for compromising acoustical and electromagnetic emanations were addressed in two separate documents. These laboratory test standards were prepared by SCOCE and superseded FS-222. They were approved by the USCSB and promulgated as Information Memoranda under the National COMSEC/EMSEC Issuance System. NACSEM 5100 is the Compromising Emanations Laboratory Test Standard for Electromagnetic Emanations and NACSEM 5103 is the Compromising Emanations Laboratory Test Standard for Acoustic Emanations. These documents are intended only to provide for standardized testing procedures among U.S. Government Departments and Agencies. They were in no way intended to establish standardized TEMPEST suppression limits for all U.S. Government Departments and Agencies. Under the terms of the USCSB's National Policy on Compromising Emanations (USCSB 4-4), U.S. Government Departments and Agencies are responsible for establishing their own TEMPEST programs to determine the degree of TEMPEST suppression which should be applied to their information-processing equipments.

In January 1971, NSA published KAG-30A/TSEC, Compromising Emanations Standard for Cryptographic Equipments. This standard represented our first effort to establish standardized testing procedures and limits for controlling the level of compromising emanations from cryptographic equipments.

DCA Circular 175-6A was superseded by DCA Circular 300-175-1 in 1969, which in turn was replaced by MIL HDBK 232 on 14 November 1972.

Before I summarize the TEMPEST situation and give you my personal conclusions about its security implications, I should make it clear that there are a number of topics in this field which comprise additional problems for us beyond those I've talked about at length. There are, for example, about a half-dozen phenomena beyond the eight I described to you; but those eight were the most important ones. I have hardly touched on the role of industry or on the program designed to train manufacturers and mobilize their resources to work on the problem. I have mentioned on-site empirical testing of operating installations only in the case of Fort Meade—actually, each of the Services has a modest capability for checking out specific installations and this "mobile test program" is a valuable asset to our work in correcting existing difficulties. For example, the Air Force, Navy, and ourselves have completed a joint survey of the whole signal environment of the island of Guam. As you know, B52 and many Navy operations stage there. As you may not know, a Soviet SIGINT trawler has loitered just off-shore for many months. Are the Soviets simply gathering plain language communications, or are they able to exploit compromising emanations?

Another problem area is the matter of providing guidelines for the design of complete new government buildings in which they expect to use a good deal of equipment for processing classified information. How do we anticipate the TEMPEST problems that may arise and stipulate economical means for reducing them in the design and layout of the building itself? We consult with the architects for new federal office buildings, suggesting grounding systems and cable paths that will minimize TEMPEST suppression cost when they decide to install equipment.

Finally, equipment designers face some specific technical difficulties when certain kinds of circuits have to be used, or when the system must generate or handle pulses at a very high bit rate. These difficulties stem from the fact that these pulses are characterized by very fast "rise-times".

They peak sharply, and are difficult to suppress. When this is coupled with the fact that on, say, a typical printed circuit board, there just isn't room to get this physical separation between lots of wires and components that ought to be isolated from one another, then mutual shielding or electrical "de-coupling" is very difficult. R&D has published various design guides to help minimize these problems, but they continue to add cost and time to our developments. With crypto-equipment, problems can be particularly acute because, almost by definition, any cryptomachine forms an interface between RED (classified) signals, and BLACK (unclassified) ones, for you deliver plain text to it, and send cipher text out of it—so the notion of RED/BLACK signal separation gets hazy in the crucial machinery where one type of signal is actually converted to the other.

SUMMARY

We have discussed eight separate phenomena and a host of associated problems. We have identified a number of countermeasures now being applied, the main ones being the use of low-level keying, shielding, filtering, grounding, isolation, and physical protective measures. We have traced a program over a period of more than 20 years, with almost all the advances having been made in the last decade, and a coherent national program having emerged only in the past few years. My own estimate of the overall situation is as follows:

1. We should be neither panicked nor complacent about the problem.
2. Such evidence as we have been able to assemble suggests that a few of our installations, but very few of them, are probably under attack right now. Our own experience in recovering actual intelligence from U.S. installations under field conditions suggests that hostile success, if any, is fragmentary, achieved at great cost and—in most environments—with considerable risk.
3. There remain a number of more economical ways for hostile SIGINT to recover intelligence from U.S. communications entities. These include physical recovery of key, subversion, and interception and analysis of large volumes of information transmitted in the clear. But during the next five years or so, as our COMSEC program makes greater and greater inroads on these other weaknesses, and especially as we reduce the amount of useful plain language available to hostile SIGINT, it is logical to assume that that hostile effort will be driven to other means for acquiring

intelligence as more economical and productive, including increased effort at TEMPEST exploitation. Already, our own SIGINT effort is showing a modest trend in that direction. As knowledge of the phenomenon itself inevitably proliferates, and as techniques for exploitation become more sophisticated because of ever-increasing sensitivity of receivers, heightening fidelity of recording devices, and growing analytical capabilities, the TEMPEST threat may change from a potential one to an actual one. That is, it will become an actual threat *unless* we have been able to achieve most of our current objectives to suppress the equipments we will then have in our inventory and to clean up the installations in which those equipments will be used.

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A HISTORY OF U.S. COMMUNICATIONS SECURITY (U)

THE DAVID G. BOAK LECTURES

VOLUME II

NATIONAL SECURITY AGENCY
FORT GEORGE G. MEADE, MARYLAND 20755

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JULY 1981

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INTRODUCTION

(U) The first volume of this work was completed in 1966, and except for a brief update in 1972 treating mainly our part in the failure in Vietnam, has remained essentially unchanged. The purpose of the ensuing essays is to provide some historical perspective on some of the trends, concepts, ideas, and problems which have either arisen in the past decade or so or have persisted from earlier times. The material is intended to be essentially non-technical, and is for relative newcomers in our business. Our nuts and bolts are treated in considerable depth in KAG 32B/TSEC. It is commended to readers seeking detail, particularly on how our systems work and the specifics of their application.

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POSTSCRIPT ON SURPRISE

(U) We've encountered no serious argument from anybody with the thesis that COMSEC - a key ingredient of OPSEC - may help achieve surprise, nor with the correlative assertion that fewer and fewer major activities can be planned and executed these days without a large amount of supporting communications to coordinate, command and control them, nor even with the assertion that, without security for those communications, surprise is highly unlikely.

~~(C)~~ But, with all that said and accepted by customers, we may still be faced with the quite legitimate question: "What is its value - How much is it worth?" Is a KY-38 the right choice over rounds of ammunition to an assault platoon? Or all the other trade-offs you can imagine when we cost money, take space, consume power, use people, complicate communications, or reduce their speed, range, reliability, capacity, or flexibility. Can we quantify its value? Rarely, I fear, because we can so seldom show the success or failure of some mission to have been categorically and exclusively a function of the presence or absence of COMSEC. Even in the drone anecdote related in the following OPSEC chapter, where we'd like to credit a few crypto-equipments with the savings of several hundred million dollars worth of assets, there were other contributors like improved drone maneuverability and command and control, and increased EW support to disrupt North Vietnam's acquisition radars.

(U) In a straight military context, however, we know of one major effort to quantify the value of surprise. Professor Barton Whaley of Yale undertook to measure success and failure in battle as a strict function of the degree of surprise achieved by one side or the other. He used Operations Research techniques in an exhaustive analysis of 167 battles fought over a period of many years in different wars. He confined his choice of battles to those in which there were relatively complete unit records available for both sides and chose them to cover a wide variety of conditions which might be construed to affect the outcome of battle - terrain, weather, numerical or technical superiority of one side or the other, offensive or defensive positioning, and so on.

(U) His measures for "success" were the usual ones: kill ratios, casualty ratios, ordnance expenditures, POW's captured, and terrain or other objectives taken. He found that, regardless of the particular measure chosen and the other conditions specified, success was most critically dependent on the degree of surprise achieved. He found:

	<i>No. of cases</i>	<i>Average casualty ratio</i> <i>(friend : enemy)</i>
SURPRISE:	87	1: 14.5
NO SURPRISE:	51	1: 1.7
NO DATA:	29	

(U) The above is contained in Professor Whaley's book (still in manuscript form) *Strategem: Deception and Surprise in War*, 1969, p. 192.

(U) When the extreme cases were removed, the average casualty ratios were still better than 1:5 where surprise was achieved, vs. 1:1 when it was not (*Ibid.* p. 194).

(U) He further asserts that, nuclear weapons and missile delivery systems "...raise the salience of surprise to an issue of survival itself. . ." (*Ibid.*, p. 207).

(U) These seem to be facts worth noting in persuading people that their investment in COMSEC will be a good one; they'll get their money back, and then some. I have to confess, however, that the analogy between Whaley's findings and what COMSEC can do is flawed. For, Dr. Whaley was a World War II deception expert, and he believed that the best way to achieve surprise is through deception rather than through secrecy.

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OPSEC

(U) Since earliest times, one of the basic principles of warfare has been surprise. In fact, some early Chinese writings on the subject are quite eloquent. A strong case can be made that, seen broadly, a major purpose of COMSEC - perhaps its overriding purpose - is to help achieve surprise by denying enemy foreknowledge of our capabilities and intentions. The principle applies not only to strategic and tactical military operations but to the fields of diplomacy, technology, and economic warfare as well. In fact, it extends to almost any adversarial or competitive relationship.

(U) Operations Security (OPSEC) is a discipline designed fundamentally to attain and maintain surprise, particularly in military operations. In fact, I have seen drafts of an Army update of their doctrine on Principles of Warfare in which OPSEC is formally recognized as a supporting factor in the treatment of surprise.

~~(S-CCO)~~ The history of OPSEC and our involvement in it flows along the following lines: By 1966, both intelligence sources and after-action reports had made it abundantly clear that the North Vietnamese had sufficient foreknowledge of ARC LIGHT (B-52) and ROLLING THUNDER (tactical aircraft) raids to render many of those operations ineffective. A concerted effort began in an attempt to determine the sources of that foreknowledge. To that end, JCS assembled a group which included DIA, the Services and ourselves. NSA was a player, both because SIGINT had been the source of some of the most convincing evidence of enemy foreknowledge and because communications insecurities were thought to be a prime candidate as the culprit.

~~(C-CCO)~~ Early on, the Group decided that an all-source effort should be made. Three basic potential sources for the foreknowledge were soon established - hostile SIGINT exploiting U.S. signals insecurities; HUMINT (Human Intelligence) in which agents could physically observe and report on the planning and execution of missions; and operations analysts deducing the nature of forthcoming activity from an examination of stereotypic (repetitive) patterns revealed by our past activity.

~~(C)~~ OPSEC emerged as a formal discipline when it was decided, I believe at the urging of NSA representatives, that a methodology should be devised which would *systematize* the examination of a given operation from earliest planning through execution: a multi-disciplinary team would be established to work in concert, rather than in isolation; and its membership would include experts in COMSEC, counter-intelligence, and military operations. They would look at the entire security envelope surrounding an operation, find the holes in that envelope, and attempt to plug them.

(U) A most important decision was made to subordinate this OPSEC function to an operations organization, rather than to intelligence, security, plans, or elsewhere. It was thought essential (and it proved out, in the field) that OPSEC not be viewed as a policing or IG (Inspector General) function because, if it was so perceived, operators might resent the intrusion, circle their wagons and not cooperate as the team dug into every step taken in launching an operation. Rather, they were to be an integral part of Operations itself, with one overriding goal - to make operations more effective.

(U) Operations organizations (the J-3 in Joint activities, G-3 or S-3 in Army, N-3 in Navy, and A-3 in Air Force) generally seem to be top dogs in military operations. They are usually the movers and shakers, and alliance with them can often open doors and expedite action. And so it was with the formal OPSEC organization.

~~(S)~~ In a remarkably swift action, the JCS established an OPSEC function to be located at CINCPAC (Commander in Chief, Pacific), shook loose 17 hard-to-get billets, and the OPSEC team known as the Purple Dragons was born. An NSA planner and analyst out of SI was a charter member and was dispatched to the Pacific. The Dragons got added clout by being required to brief the Joint Chiefs of Staff and the President's Foreign Intelligence Advisory Board on their progress each 3 months. They were to support all operations, not just air strikes. They were given a free hand, travelled constantly all over the Pacific, more or less wrote their charter as they went along, and repeatedly pin-pointed the major sources of operations insecurity. Sometimes they were able to help a commander cure a problem on the spot; other problems were more difficult to fix. In the case of air strikes, three of the biggest difficulties stemmed from the need to notify

ICAO (International Civil Aeronautical Organization), other airmen, and US and allied forces of impending operations well before the fact.

~~(C)~~ Altitude reservations (ALTREV's) were filed with ICAO, and broadcast in the clear throughout the Far East. Notices to Airmen (NOTAM's) specified the coordinates and times of strikes so that they would not fly through those areas, and these notices were posted at U.S. air facilities everywhere. Plain language broadcasts (called Heavy Artillery Warnings) saturated South Vietnam specifying where B52 (ARC LIGHT) strikes were to take place. U.S. officials were obliged to notify and sometimes seek approval of South Vietnamese provincial officials so that they could warn villagers of the coming action.

~~(C)~~ Some of these problems associated with ARC LIGHT operations were eventually solved by blocking out large air corridors to a single point of entry into SVN airspace; the Heavy Artillery warnings, once transmitted hours before a strike, were withheld until 60 minutes or less before the time on target.

~~(S)~~ In general, set patterns of operations were rather prevalent in land, sea, and air activity. Ground attacks at dawn were the rule not the exception; hospital ships were pre-positioned off amphibious landing areas; there were runs on the PX before troops moved out of garrison to combat. Major movements of ground forces were preceded by weeks of predictable and observable activity, arranging logistics, setting up convoy routes and bivouacs, coordination with supported and supporting forces and so on. The failure to take COSVN (the North Vietnamese "Central Office for SVN" in the Parrot's Beak area of Cambodia) was almost certainly the result of the huge flurry of indicators of impending attack that preceded it by at least three days.

~~(C)~~ HUMINT vulnerabilities were pervasive. North Vietnamese and Viet Cong agents had infiltrated most of the country. Yet the Purple Dragons were never able to demonstrate that agent reporting was a dominant factor in enemy anticipation of U.S. action. Rather, communications insecurities emerged as the primary source of foreknowledge in fully two-thirds of the cases investigated. On occasion, a specific link or net was proven to be the source of foreknowledge of a given operation, at least for a time.

~~(S)~~ A classic case involved the drone reconnaissance aircraft deployed out of South Vietnam to overfly North Vietnam, gather intelligence, and return. By late 1966, the recovery rate on these drones had dropped to about 50%. This deeply concerned us, not only because of the loss of intelligence and of these expensive (\$500K at the time) aircraft, but also because we were certain that North Vietnamese anti-aircraft assets could not possibly have enjoyed such success without fairly accurate foreknowledge on where these planes would arrive, at about what time, and at what altitude. The Purple Dragons deployed to SVN, and followed their usual step-by-step examination of the whole process involved in the preparations made for launch and recovery, and the configuration and flight patterns of the mother ship and the drones themselves, the coordination between launch and recovery assets, including the planning message exchanged. The mother ships staged out of Bien Hoa in the southern part of SVN; the recovery aircraft out of DaNang to the North. Within a few days, the Dragons zeroed in on a voice link between the two facilities. Over this link flowed detailed information, laying out plans several days and sometimes for a week or more in advance on when and where the drones would enter and egress from North Vietnam. The link was "secured" by a weak operations code; the messages were stereotyped, thus offering cryptanalytic opportunities, and their varying lengths and precedences offered opportunities for traffic analysis. In short, the North Vietnamese might be breaking it, or enough of it to get the vital where and when data they needed to pre-position their anti-aircraft assets (surface to air missiles, anti-aircraft batteries, and fighter aircraft) to optimize the chance of shootdown.

~~(S)~~ As a check, the Dragons manipulated some messages over the link, with fascinating results. (See the March and April 1979 issues of *CRYPTOLOG* for some further details on this account at somewhat higher classification than possible here.) The OpCode was replaced quickly with a pair of fully secure KW-26 equipments. Starting the next day, the loss rate dropped dramatically. A few months later, it began a sudden rise, suggesting that the North Vietnamese had discovered a new source of information. The Purple Dragons revisited, and reassessed the problem. This time they concluded that the unique call signs of the Mother Ships were being exploited. The call signs were changed, and losses fell again, for a few weeks. The final solution was to put NESTOR aboard, and again the loss rate dropped so drastically that, by the end of the drone activity, only one or two drones were lost to enemy action annually in contrast to as many as two or three a week in the early days.

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~~(C)~~ OPSEC is slowly being institutionalized. OPSEC elements are established in the JCS and at most Unified and Specified Commands. Service organizations are turning increasingly to the discipline but not, as you might expect in peacetime, with great enthusiasm. We have a modest capability for OPSEC in S as well, used largely in support of joint activity or, on request, to assist other organizations. We have also looked inward with the OPSEC methodology in helping DDO maintain the secrecy of his operations, and as still another cut at the general problem of computer security in DDT. Results have been useful.

~~(C)~~ The principal innovation in OPSEC methodology since early times was the development in S1 of a decision analysis routine called VULTURE PROBE to quantify the value of various COMSEC measures by showing how the probability of an enemy's reaching his objectives is reduced as a function of the COMSEC steps we apply. This in turn helps us to decide which information most needs protection, and the relative significance of the many individual security weaknesses an OPSEC survey is likely to uncover.

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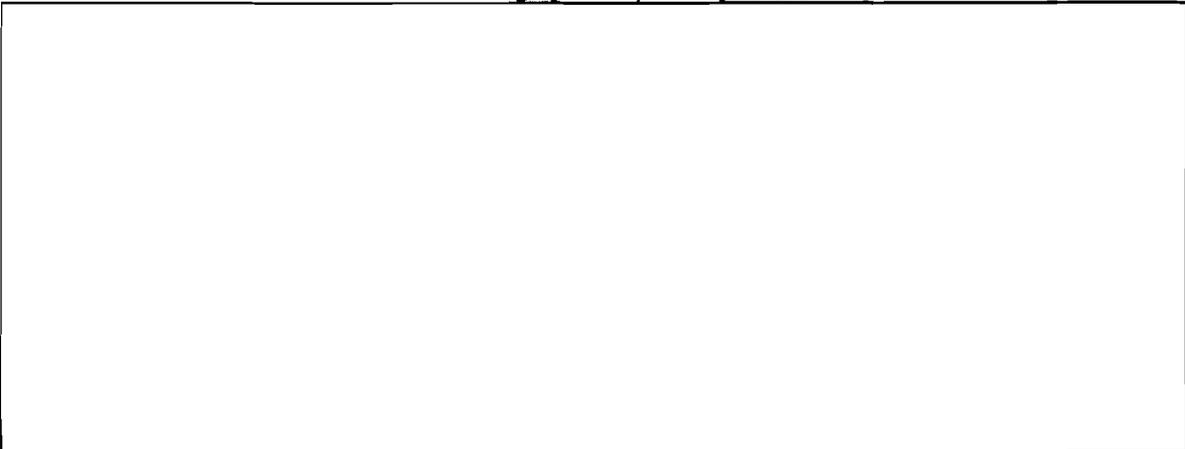
ORGANIZATIONAL DYNAMICS

~~(C)~~ The first Volume described a relatively simple, straightforward functional organization for COMSEC in NSA - the traditional R&D organization for system invention and development, an Engineering organization to manage the production of equipments in quantity, a Materials organization to supply supporting keys and other materials, a Doctrinal organization to approve and regulate use, and a few supporting Staffs. (Please, young people in the line, don't laugh at the sort shrift Staffs usually get in description of who does what. It is more likely than not that it will be to your career advantage to have such an assignment for at least a little while before you are done. I predict that then your perspective on their importance and value will change even though you may now percieve that they are mostly in the way - particularly if you are trying to get something/anything done in a hurry. In general, (but obviously not always) they enjoy the luxury and suffer the uncertainties of having time to think things through.

~~(C)~~ Our organizational structure changed over time, generally in response to changed requirements, priorities, and needed disciplines. Down in the noise somewhere (except in the scruffy gossip mill) were other factors like personalities, managerial competence, office politics, and so on. The original Doctrine/Engineering/Material triad survived for slightly more than 20 years. Exploding communications technology, quantum jumps in system complexity, speed, capacity, efficiency, reliability, and quantity left our engineers in R and S and our production people strangely unstressed. They had kept pace with technology breakthroughs over the years, and sometimes paced them.

~~(C)~~ The Doctrinal organization, however, was beginning to burst at the seams. Here was a group that had had little change in numerical strength since its inception, dominated by liberal artists except in cryptanalytic work, trying to cope with technologies so complex in the requirements world that they were hard put to understand, much less satisfy those requirements. A DoD Audit team found, in S, too great a concentration on the production of black boxes and made strong recommendations that we change to a "systems" approach to more fully integrate our cryptosystems into the communications complexes they support.

~~(C)~~ So, in 1971, came our first major re-organization and S4 (now S8) was born (out of Doctrine by Barlow). Its mission was to get cryptography *applied*. What seemed required was a cadre of professionals, including a liberal infusion of engineers, computer scientists, and mathematicians, in a single organization who would be the prime interface with our customers to define *system* security requirements and to assist in the integration of cryptography to that end. There were, of course, mixed emotions about dilution of our scarce technical talent into a kind of marketing operation, but it paid off.

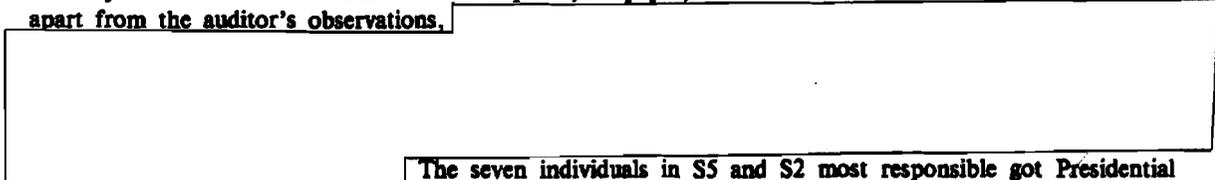


~~(C)~~ A couple of years later (July 1974), another audit report recommended better centralized management and control of cryptographic assets in Government. The Acquisition staff was converted to a full scale line organization (S5) in part in response to that recommendation. There is a persistent view that the ability of an organization to get something done is inversely proportional to the number of people on staff. The

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Marine Corps is the arch-type: lean and mean; lots of fighters, little excess baggage in the form of staffers - logisticians, budgeteers, planners, policy makers, clerks, typists, researchers, educators, administrators, and the like.

~~(C-NF)~~ A hoax, of course. The Navy "staffs" for them. No matter what you call it or where you put it, much of that "drudgery" has to be done. The Chief, S5 took some jibes in the form of the assertion that the only reason for the new Office was to improve, on paper, our line-staff ratio. The truth was that, quite apart from the auditor's observations,



The seven individuals in S5 and S2 most responsible got Presidential citations under a program recognizing major savings in Government. 28% of the total Government savings getting special recognition that year was the work of our people.



~~(C)~~ Now, DDC had five offices, four staffs, and these major projects all demanded managerial time and attention. So, in part to reduce a growing problem of span of control, a new office (S7) was formed in 1977 incorporating all but the HAMPER activity into four Special Project Offices (SPO's), each with Division level status. At the same time, the S1 cryptanalytic organization was split out to form the nucleus of another new Office for COMSEC Evaluations (S6) on a systems-wide basis to include cryptosecurity, TEMPEST, TRANSEC, and physical security.

(U) Ultimately (1978) S4 and S7 were merged into a single Office, S8, which brings us up to date.

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THREAT IN ASCENDANCY

~~(C)~~ In olden times, most of our programs, whether in equipment development, TEMPEST, or security procedures were driven largely by our view of COMSEC weaknesses - our *vulnerabilities* - more or less independent of judgments made on the ability of an opponent to exploit them. We assumed hostile SIGINT to be at least as good as ours, and used that as a baseline on what might happen to us. If we perceived a weakness, we would first try for a technical solution - like new crypto-equipment. If the state of that art did not permit such a solution, or could do so only at horrendous expense, we'd look for procedural solutions and, those failing, would leave the problem alone.

~~(C)~~ So our priorities were developed more or less in the abstract, in the sense that they related more to what we were able to do technologically or procedurally than to the probabilities that a given weakness would be exploited in a given operating environment. In short, we did not do much differentiation between vulnerabilities which were usually fairly easy to discover, and threats (which were more difficult to prove) - where threats are fairly rigorously defined to mean demonstrated hostile capabilities, intentions, and/or successes against U.S. communications. The accusations of overkill touched on earlier in part stemmed from that approach.

~~(C)~~ The thrust towards gearing our countermeasures to threat rather than theoretical vulnerability was healthy, and driven by a recognition that our resources were both finite and, for the foreseeable future, inadequate to fix everything. In fact, one of the reactions of an outside analyst to our earlier approach was, "These nuts want to secure the world." Some still think so.

(U) After Vietnam, there was a strong consensus in this country that the U.S. would not again commit forces to potential combat beyond show-the-flag and brush fire operations for a decade or more unless some truly vital interest was at stake - like the invasion of our country. There was a correlative view that such an event would almost certainly not arise in that time frame, and we focussed increasingly on detente and economic warfare.

~~(C)~~ These views, in turn, suggested that threats would be directed more towards strategic C³ communications than tactical ones and that, accordingly, our priorities should go to the former. So, what did we do? We made the largest investment in tactical COMSEC systems in our history - VINSON. We went all out in support of TRI-TAC, a tactical "mobile" system with more engineers out of R¹ and S assigned to it than the totality of effort in the strategic communications arena. Further, the bulk of this effort was in support of securing voice and data only on short *wire lines* (a few kilometers) radiating from the TRI-TAC switches.

~~(C)~~ How come? I think it was simply a matter of doing what we knew how to do - arrange to secure multiple subscribers on wire in the complex switching arrangement of the TRI-TAC concept. We did not know how to integrate tactical radios within that concept, and so deferred that problem (called Combat Net Radio Interface) while we built our DSVTs, DLEDs, and elaborate electronic protocols to effect end-to-end encryption. We're getting to it now, but the lion's share of the initial effort was devoted to protecting the least vulnerable communications - the ones on short wire lines in the field.

(U) That sounds like a lot, after all. In peace time, though, most of that kind of information is readily and continuously available through other means - notably HUMINT gathered through routine physical observation, from agent reports, from our own voluminous open publications. . .

(U) I hasten to add that I'd be the last one to push that argument too far. If we denigrate the need for some COMSEC program each time we can point out an alternative way for the information to be obtained,

we can talk ourselves out of business. We do, always, need to be sure that voids in COMSEC do not provide the quickest, most reliable, and risk-free ways to obtain our secrets.

~~(S)~~ Despite this major aberration—failure to use threat to determine priority—in the general case, the record has been good. As noted, it was certainly the driving force behind the HAMPER program. It accelerated our work in telemetry encryption. It may hasten the modification or abandonment of some marginally secure systems. It certainly precipitated major improvements in some of our systems and procedures for strategic command and control. In its first real application, it changed an unmanagably ambitious TEMPEST program into one that geared suppression criteria to physical environments and information sensitivity in information processors. And it has shaken loose a variety of efforts to improve physical and transmission security.

(U) A caveat: While nothing gets a user's attention like documented proof that communications *he* thinks are sensitive are being read by an opponent, several things should be borne in mind before telling him about it. Foremost is the fragility of the source of the information (the "proof") you have. Secondly, it is worse than useless to go out and impress a user with a problem unless you have a realistic solution in hand. No matter how dramatic the evidence of threat, if we simply go out and say, "Stop using your black telephone," it's likely to be effective for about two weeks. Don't jeopardize a good source for that kind of payoff.

~~(C)~~ Finally, the results of our own monitoring and analysis of communications, at best, prove vulnerability, not threat, and are often remarkably ineffective. Nothing brought this home more persuasively than the Vietnam experience. Monitoring elements of all four Services demonstrated the vulnerability of tactical voice communications again and again. This did not show that the NVA or VC could do it. It was first argued that they weren't engaged in COMINT at all. Next, that even if they were able to intercept us, they couldn't understand us, especially given our arcane tactical communications jargon. Third, even given interception and comprehension, they could not react in time to use the information.

~~(C-CEO)~~ It took years to dispel those notions with a series of proofs in the form of captured documents, results of prisoner and defector interrogations, some US COMINT and, finally, the capture of an entire enemy COMINT unit: radios, intercept operators, linguists, political cadre and all. Their captured logs showed transcriptions of thousands of US tactical voice communications with evidence that their operators were able to break our troops' home-made point-of-origin, thrust line, and shackle codes *in real time*. The interrogations confirmed their use of tip-off networks (by wire line or courier) to warn their commanders of what we were about to do — where, when, and with what force.

(U) Lamentably, even with that kind of proof, the situation didn't improve much because our "solution" was NESTOR: users did not like that equipment, and they *had* to communicate, anyhow.

LPI

(U) A traditional way to enhance the security of a transmission is to make it difficult to intercept. The options range from whispering (or the radio equivalent, use of minimum power) to the use of cryptography to spread the transmitted signal unpredictably over a large swatch of the frequency spectrum. In between are armed couriers, physically or electronically protected distribution systems (wire line and, lately, fibre optics), high directivity narrow beam communications (directional antennae and lasers), and hopping randomly and rapidly from one frequency to another.

~~(C)~~ The impetus for the upsurge of interest in LPI (low probability of intercept) radio transmission systems has come not so much from their potential to *secure* communications as from the need to prevent jamming. In other words, it's more a question of communications reliability - assuring delivery - than communications security. As noted in Volume I, this fact raises interesting questions on roles and missions for us - anti-jam being traditionally an EW (electronic warfare) matter, not COMSEC, so why were we "intruding" in this arena? The community seems now to accept the idea that we should (we say "must") participate if cryptographic techniques are employed to lower intercept probability. Thus, while we may provide the key generator to spread or hop a signal, we don't get involved in non-cryptographic anti-jam techniques like the design of directional antenna or brute force very high power transmitters to assure message delivery.

(U) While a primary function of LPI is to prevent jamming, a second one of great importance is to provide protection against an opponent's use of DF (direction finding) to locate mobile military platforms when they transmit. If he can't hear a transmission, he has no way of determining where it came from.

~~(S-NF)~~ Much heavier anti-jam emphasis has arisen because of several developments. First, in the last decade, the focus on Command and Control and the criticality of those communications used to direct forces has intensified, with a recognition that we would be enormously handicapped if those communications were denied to us. The second reason for emphasis stems from growing evidence of Soviet doctrine and supporting capabilities to use EW as a major element of their military tactics and strategy. Finally, some of our forces - notably the Air Force - having begun exercising in "hostile" EW environments, found their capabilities significantly degraded, and thus confirmed a very high vulnerability.

~~(S)~~ In fact, we were stunned when an Air Force study in the European tactical air environment suggested that their vulnerabilities to jamming were greater than those stemming from plain language air-to-air and air-to-ground voice communications. From this CGTAC reportedly concluded that, since they might not be able to afford both COMSEC and anti-jam systems, they would opt for the latter. One senior Air Force officer reportedly said he needed an anti-jam capability so badly he would trade aircraft for it. With a lot of backing and filling, and more extensive study, we helped persuade the Air Force that they really needed both anti-jam and COMSEC. Army had clearly come to that conclusion as early as 1974 when specifications for their new tactical single channel radio (SINCGARS) called for both a COMSEC module and an anti-jam module. The Army, of course, was also the first to get serious about the business of implementing daily changing call signs and frequencies. I believe their and our motivation in pushing for these procedures was to provide defenses against conventional traffic analytic attacks to determine OB (order of battle). But there is an anti-jam advantage as well - by hiding a unit's identity (callsign change) and his location in the spectrum (frequency change), you force the jammer into broadsides - a mindless barrage, not a surgical strike against the specific outfits that worry him most. That, in turn, exposes the jammer himself to hazard - our location of this interfering signal and, perhaps, launching of homing weapons or something else against him.

~~(C)~~ One of the more insidious arguments we faced in some circles where anti-jam was asserted to be more important than COMSEC arose from the fact that ordinary cryptography does not add to the resistance of a transmission to jamming. If you can jam the clear signal, you can jam it in the cipher mode. Further, a smart jammer can work against most encrypted signals more efficiently than against plain text, use less power and be on the air for much briefer intervals. This is true, because all the jammer need do is knock the cryptographic transmitters and receivers out of sync or disrupt the initialization sequences that prefix

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most encrypted traffic. This is not the case where we employ CTAK (cipher text auto-key) or where synchronization is dependent on internal clocks rather than timing elements of the cipher text itself. All the others are vulnerable if the jammer can stop them from getting into sync in the first place by repeatedly attacking preambles.

SARK—SOME CAUTIONARY HISTORY

~~(C)~~ SAVILLE Automatic Remote Keying (SARK), now usually referred to merely as "Remote Keying," is a subject of mild controversy among the elders as to its origins and original goals. One school of thought (memory) insists it was conceived to solve the logistics problem attendant on continual physical distribution and re-distribution of individual hard copy keys to every holder in every net, with the fall-out benefit of reducing security problems by having fewer copies of compromise-prone keys in the pipe-line, in storage, or in operating locations. The other school recalls just the opposite - an initial drive to find a technical solution to the growing problem of key list compromise - particularly through subversion of cleared individuals - and the logistics benefits a matter of serendipity.

~~(C)~~ Either way, remote keying was the biggest conceptual breakthrough in ways to set up crypto-equipments since the days of the card-reader. But both these potential benefits may be in some jeopardy.

~~(C)~~ VINSON, the prototype vehicle for remote keying, gets its rekeying variable (its "unique" key) from one of three sources: direct from a key variable generator (the KVG) usually held at net control, or from an electronic transfer device (ETD) which has been previously loaded from a KVG, or from a punched key tape (manufactured by S3) which can be loaded into an ETD with a special tape reader.

~~(C)~~ For a typical, small, tactical radio net (10-20 holders) the idea was that each subscriber would either go to net control and have his equipment loaded with his variables, or net control would dispatch a courier with an ETD to load his variables *in situ*. Thereafter, he would operate independently of any variables except those electronically stored in his machine until his unique rekeying variable required supersession (usually *one month* unless compromise required sooner change). Meanwhile, he would be rekeyed remotely and independently of any key except that in his machine. No ETD's, no tapes, no couriers, no material to protect except for the keyed machine itself.

~~(C)~~ Despite repeated demonstrations that the concept would work during OPEVAL (operational evaluation) and in a number of nets in Europe where VINSONs were first implemented, it has not, at least so far, worked out that way.

~~(C)~~ We have evidently so sensitized users to the crucial importance of their key that they fear leaving it in their equipments when they are not actually in use. We have conditioned them with forty years of doctrine calling for key removal and safe storage when the equipment is not attended or under direct guard. As a natural consequence, it was an easy step to zeroize equipments at night, hold key tapes or loaded ETD's, and rekey themselves in the morning. Result? Easily recovered key at most user locations, now in the form of key tapes and loaded ETD's - a substitution of one kind of readily recoverable key for another, and our physical security is not much improved over what we had with conventionally keyed systems like NESTOR and the KW-7.

~~(C)~~ Within the next few years, we expect about 140,000 equipments which can be remotely keyed to come into the inventory. At the same time, the users have ordered about 46,000 ETD's and we project the need for 10's of thousands of rolls of key tape to support them, each containing a month's settings. So we're seeing a ratio of 1 to 3 build up, instead of 1 : 10 or less as we had hoped; and our goal of making keys inaccessible to almost everybody in the system may not be realized through remote keying.

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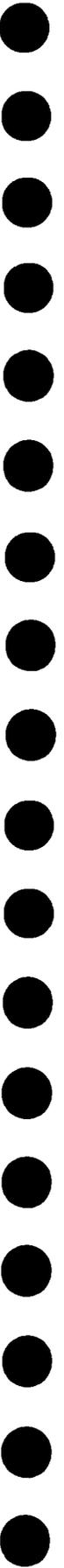


THE CRYPTO-IGNITION KEY

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PCSM

~~(C)~~ One of our most intractable problems has been to find ways to package crypto-equipment in a way which will seriously deter penetration by a smart, well-equipped opponent with plenty of time. The difficulty is not much different than is faced in the manufacture of three-combination safes. The best we can generally afford can stand up to a covert penetration effort by an expert only for 30 minutes or so, and brute force attacks, leaving evidence, can be done much more quickly than that. Yet, these safes are massive and expensive. With a crypto-box, there are added difficulties in protecting logic or resident key because X-ray devices or electronic probing may recover the information without physical entry.



~~(C)~~ For many years we have known that technologies do exist for building protective cocoons around objects that can in fact provide a very high level of resistance to tampering without triggering some alarm. When we first encountered them, we rejected them out of hand as a practical solution to our problem because these "protective membranes" as they were called, could cost on the order of \$50,000, each.

~~(S-NF)~~ But more than fifteen years have passed since our first encounter with the technique. The process has been refined, and it now appears that we *might* be able to get such packages for under \$500 apiece if we buy in large quantities. This prospect merged in the mind of J. Richard Chiles with the potential for using micro-processors to program various crypto-logics and ancillary functions in a given box. Thus the concept of PCSM - the Programmable COMSEC module - was born.

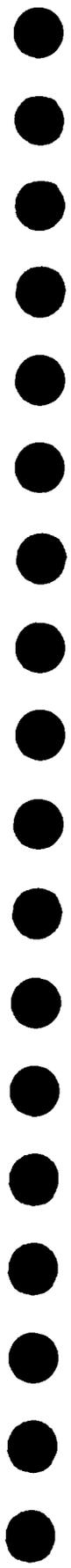
~~(S-NF)~~ The grand design was (and is) elegant. Encapsulate a micro-computer in a protective membrane. Program it with whatever crypto-logic and assorted keys are required to operate in a given net. Build into each box a unique element of logic or key so that if the membrane is defeated and the contents lost, it will affect no other subscriber's traffic. The membrane serves one function only - to provide, with high confidence, a *penalty* if penetrated. The penalty could range from (theoretically) an explosion to an alarm at some remote place. It *might* simply zap critical circuitry, disabling the machine, or obliterate all sensitive data (if we learn how to do that).

~~(S-NF)~~ Depending upon the kinds of penalties that prove practical to impose, it may be possible for the entire keyed programmed operational box to be *unclassified*, getting no protection at all beyond that which it provides for itself. Your safe, after all, is not classified. Only its contents. And if all its contents evaporated if somebody (anybody, including you) were to open it, there'd still be no problem. Alternatively, and perhaps more feasibly, it might operate like a bank vault. The money doesn't disappear when somebody breaks in, but other things (alarms) are likely to happen to prevent him from making off with it.

~~(S-NF)~~ A final element in the concept is the use of some central office, switch, net-controller, NSA (!) or some such to electronically check the presence and health of each box. Thus, equipments in storage or in operational locations could not be removed, physically intact without detection, and internal malfunctions in the protective system could be determined without local effort.

~~(C)~~ The goal is not a "perfectly" secure system - rather one good enough to make the risk of detection to an opponent unacceptably high.

~~(S-NF)~~ Maybe by the time somebody writes Volume III of this work, PCSM can be discussed in the present tense. I hope so, because it constitutes the biggest conceptual step forward since remote keying. Most of this material is classified SECRET to help us achieve technological surprise, and it should *not* be discussed outside NSA without prior approval from DDC.



NET SIZE

—(C)—The cryptosecurity implications of very high volumes of traffic using the same key have not been a dominant factor in determining net size in most of our cryptomachines for many years. Rather, we have opposed very large networks sharing the same key in recognition of the fact that the likelihood of physical compromise rises with the number of copies of materials we make and the number of people to whom it is exposed. Correlatively, the longer a given item is in existence the more opportunities for its compromise arise, and supersession rates are based, in part, on that fact. (A physical security Vulnerability Model has been devised which permits some trade-offs between these two facts - larger nets with more rapid supersession rates, and vice versa.)

—(C)—In olden times, there were limitations on the basic sizes of many communications nets themselves and this put natural limits on shared keying materials when these nets were secured. Now, world-wide compatible communications capabilities are much more prevalent, and operational demands call for more very widely held keys for use in these networks. Eventually, however, there is a sticking point where the risk of compromise becomes prohibitive.

—(C-NF)—Although we've never had any hard statistical probability in our hip pockets, we have generally felt comfortable with net sizes on the order of 250-400 holders, but have tolerated a few nets with upwards of 2000 holders, one KW-7 system with 4900 keys, and the horrendous KI-1A net of 5,945 copies. The rationales for accepting some of the larger nets are sometimes tortured. Instead of looking only at some rough probability of compromise as a function of exposure, we look also at the environment of use - systems in confined enclaves on shipboard seem less vulnerable to compromise than in large plants with many people milling about, or in small field locations where secure structures may not be available. Some systems can be subjected to special protective measures - notably two-man controlled materials - that may offset the existence of large copy counts.

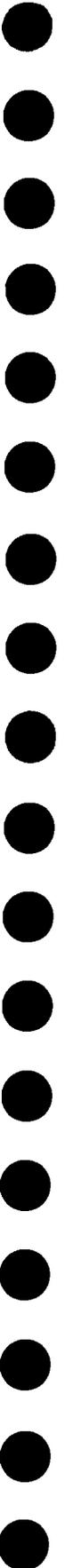
—(C)—The sensitivity or importance of the traffic in given networks may vary greatly, thus affecting the motivations for hostile elements to risk acquiring key, and the long-term security impact should compromise in fact occur. Finally, of course, traffic perishability affects our judgments. In the classic case of KI-1A, we could not care less about the compromise of the key to the world at large one minute after the key is superseded. (This system for identification of friend or foe is useful to any enemy only if he can acquire it before or while it is being used so that he can equip his forces with a means to be taken for a friend.)

—(S-NF)—Still and all, the subjectivity inherent in this approach - as in most physical security judgments - drives us nuts. We are being asked to "quantify" the unquantifiable - the integrity of our people; the physical security conditions at more than 3000 separate cryptographic accounts and the tens or hundreds of individual locations they each may serve; the "value" of tens of millions of messages; the opportunities for subversion, catastrophe, carelessness to result in the compromise of some number of the millions of items we issue annually - and so on. The real force behind the persistent efforts to find technological, measurable solutions to the problems of physical security stems in part from that frustration. There is a justifiable disillusion with our "doctrinal" and "procedural" remedies because enforcement is difficult, they are easy to circumvent deliberately or accidentally by friends and enemies alike, and there is no real way to determine their effectiveness. We need the technical solutions - secure packaging, remote keying, PCSM, emergency destruction capabilities, and so on.

—(S)—Meanwhile, let us not rationalize ourselves into some fool's paradise because we have such good and stringent rules and some soothing perceptions that the Soviets, say, aren't really all that proficient. Some of what we still hear today in our own circles when rigorous technical standards are whittled down in the interest of money and time are frighteningly reminiscent of the arrogant Third Reich with their Enigma cryptomachine.

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EQUIPMENT CLASSIFICATION

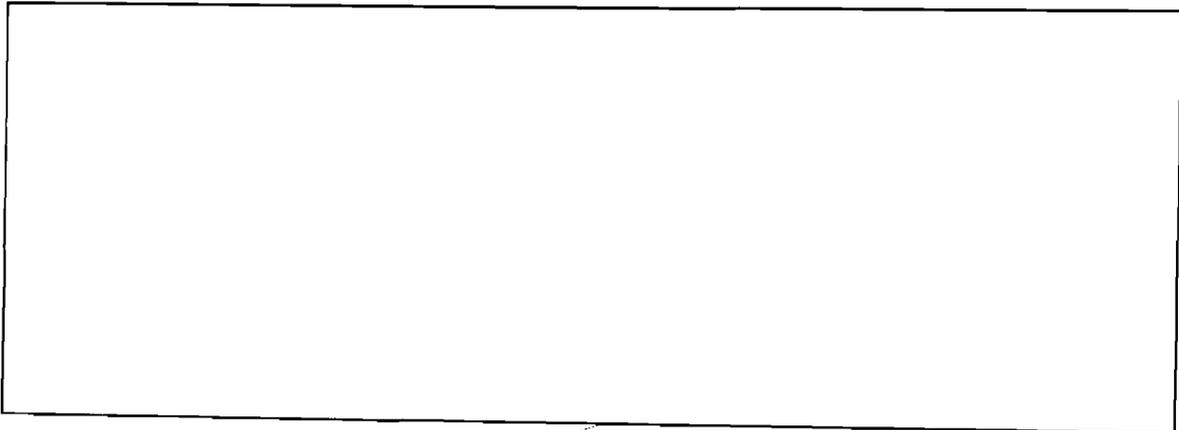
~~(C)~~ One of the more difficult doctrinal issues in our business relates to the level of protection we require for crypto-equipments. As briefly noted in the first Volume, the problem has been around for a long time. By 1970, the pressures for easing our protective criteria had become very strong. Users sought relaxed standards not only on the matter of equipment classification, but also for the whole range of rules regarding clearances, storage, guarding, accounting, access authorization, high risk deployment, key supersession rate, net size, foreign access, and compromise reporting.

~~(C)~~ A special working group was set up consisting of some of our people and representatives of the Services and a few Civil Agencies to review the matter. They found not less than 55 different sets of regulations governing various aspects of the protection of cryptomaterial including basic NSA documents and a myriad of user implementers and amplifiers of those rules. Some contradiction was inevitable. They proposed the elimination of a number of control requirements and drafted a sweeping new, simplified National Level document (NACSI 4005) which emphasized keying material protection, eased the requirements for equipment protection, and allowed classification alone to govern the protection of all other cryptomaterials (maintenance manuals, operating instructions, and so on).

(U) Central to this new departure was the concept of unclassified "Controlled COMSEC Items" (CCI), and the vision that some crypto-equipment, notably tactical equipment, could be, at NSA's discretion, unclassified (but Controlled) when unkeyed.

~~(C)~~ For the record, the background on the whole question is somewhat as follows: Since the mid-50's, various customers had been calling for unclassified equipments, particularly in the tactical arena, and had been resisted by us for reasons of COMSEC, SIGINT, and technology transfer. Throughout the '60's, pressure built as more and more systems proliferated to lower echelons, and culminated with the feed-back from Vietnam about non-use of NESTOR.

~~(C)~~ The two major reasons for declassification were the "inhibition of use" argument, and the vision of full integration of COMSEC circuitry into radios of the future - full integration being defined as inseparable and shared radio and crypto-circuitry. In that configuration, our COMSEC tail would be wagging the communications system dog with the controls classification denotes - how would such equipments be shipped, stored, and particularly, how would they be maintained? "Integration" has thus far not turned out to be the wave of the future. COMSEC modules will by and large be separable from their associated radios because the designers found it more efficient to do it that way. At this writing, only BANCROFT fully embodies the original fully integrated concept. Difficulties in protection will persist even with partial "integration," of course. At the moment, though, they don't look to be nearly as severe as we first perceived.



~~(S-NF)~~ There were seven subsidiary arguments against classification and counter-arguments for each:

- The design assumption of equipment (or logic) loss, countered by facts that such loss is not certain, not necessarily early after design or deployment, and not universal - loss to one or two countries does not equate to loss to all (on the order of 160) others.

• The CONFIDENTIAL clearance offers a low confidence in the integrity of an individual because the investigation is superficial, so what are we really buying in the way of protection? The counter: we are buying a powerful legal sanction against deliberate compromise of the system to an enemy. Lack of classification has been construed as a "near absolute defense" against prosecution - espionage laws, in practice, apply only to classified (and Formerly Restricted Data) information.

- Executive Orders setting up the classification system are awkward when applied literally to hardware - the classification system was clearly designed with two-dimensional objects (paper) principally in mind. Counter: we've nonetheless lived with it rather well. Further, the Executive Order really leaves no option: if loss of the material is judged damaging, it must be classified.

- Dollars for manpower and facilities required to protect classified hardware could be saved. Counter: Savings would not be significant given the requirement for a reasonable alternate set of controls on the equipment - particularly since *classified* keys are used in association with the equipment in operational environments.

- The design of modern equipments can provide inherent protection against logic recovery. Counters: "Secure" or tamper-resistant packaging have not panned out yet. (But see article on PCSM potential.) Similarly, early efforts for extraction resistance and automatic zeroizing have proved disappointing. Early hopes that the complexities and minuteness of micro-electronic components would make their "reverse engineering" difficult have been proven unwarranted.

- Alternative controls to classification could be devised which would provide equivalent or better protection. Counter: when we actually fielded early models of VINSON and PARKHILL as unclassified but Controlled COMSEC Items (CCI) for Service tests, the system broke down. Within a few months, we had an astonishing number of gross violations - lost chips and whole equipments;

— demonstrations of equipments - including remote keying procedures - to boy scouts and wives' clubs, and extremely casual handling. We simply could not articulate the requirements to protect these equipments despite the lack of classification. The nearly universal reaction when we fussed was "If their loss is really damaging to U.S. interests, why aren't they classified?" Without exception, in our contacts with Congressional people, we got that same reaction when they were interceding for constituents demanding a share in the market for Design Controlled (but unclassified) Repair Parts (DCRP's). We learned, the hard way, that classification does significantly lower the probability of compromise.

~~(C)~~ Probably among our less judicious moves in seeking alternative controls for tactical crypto-equipment was the notion of treating them "like a rifle" without first researching what that really meant. On the one hand, it did mean a high level of protection *in the field* because rifles were items for which individuals were personally and continually accountable. Most of these same individuals perceived that their lives might well depend on them. But crypto-equipments - at least until secure squad radios come along - are not items of personal issue, and we have by no means yet convinced most users that their lives may depend on these devices even though we think we can prove that is sometimes true.

~~(S)~~ We also found, of course, that controls over small arms in the Services aren't all that great when they aren't in the hands of individual users. The system for distribution and warehousing is evidently quite weak because DoD acknowledges that many thousands of them cannot be found, or are showing up in large quantities in the hands of various other countries, terrorist groups, the criminal element, and the like.

Losses of that magnitude in our crypto-equipment inventory would be disastrous, principally because it would put some elements of DDO out of business.

~~(C)~~ So we backed away from treating them like rifles, and toyed with the idea of treating them like radios. We had heard that such "high value" items got good control, and that protection in the field would be roughly equivalent to that expected for crypto-equipment. The argument was that classification was unnecessary because it offered no real security advantage. We approached this proposition cautiously, partly remembering the large number of tactical US radios that eventually formed the backbone of the North Vietnamese and Viet Cong radio nets, and decided to do an empirical test on the relative protection afforded to radios and crypto-boxes in the same field environment.

~~(C)~~ We enlisted the aid of Army and Air Force counter-intelligence personnel under a project called JAB. During a major exercise (REFORGER '74) in Europe where NESTOR and KI-1A equipment was deployed, we dispatched small counter-intelligence Tiger Teams to see how many crypto-equipments and how many radios they could "acquire" in the same environment. By "acquire" we meant 30 or more minutes of unrestricted access - long enough to steal equipment, extract keys, or recover the internal wiring. The results were interesting.

~~(S-NF)~~ In a few weeks, the team deployed against NESTOR-equipped Army units "acquired" dozens of radios, sometimes together with their parent jeeps and other vehicles. But when they tried to get the CONFIDENTIAL NESTOR's, they met suspicion, distrust, and were nearly caught repeatedly. They managed substantial access to only one NESTOR equipment during the entire operation. That equipment was mounted on a jeep in a guarded motor pool. It was night time, and there was a driving snow-storm. The guard was described as concentrating strictly on the business of keeping alive.

~~(C-NF)~~ Inevitably, after success at three consecutive airbases, some crusty old custodian got suspicious and started checking back on their bona fides. The word went out to AF units all over Europe and they barely escaped arrest at their next target. As you might expect, when they debriefed senior AF officials in Europe, the commanders were considerably more exercised over the fact that the team could have flown off with whole airplanes than with the security of the KI-1A.

~~(C)~~ So, in the Army case, we found a substantial difference in protective levels for radios and crypto-equipments; but in the case where radios and crypto-equipments usually were collocated - i.e., on aircraft - there was no real difference.

~~(S)~~ A much safer way for a hostile government to get at these materials is through subversion of cleared people with routine access to them. This has been done a number of times that we know of, sometimes with very serious consequences. With this technique, some American, not a foreign spy, takes all the risks of getting caught. Until he does, he can offer materials repeatedly as in the most recently publicized case of John Boyce - the employee in a cryptocenter at TRW who was reportedly involved in at least a dozen separate transactions involving sale of keying material and photographs of the logic circuits in one of our crypto-equipments. (The case is well-documented in *The Falcon and the Snowman*. Simon Schuster, 1979.)

~~(S-NF)~~ Coping with this kind of problem is, in part, what remote keying, ignition keys, tamper-resistant packaging and, on the horizon, PCSM are about.

~~(C)~~ The narrative above addresses principally the matter of classification as it relates to crypto-equipment. There follows a more generic treatment of what underlies our efforts to protect cryptographic information in

general, and offers a perspective on the kinds of information a SIGINT organization finds useful in doing its job.

~~(S)~~ NSA spends tens of millions of dollars and tens of thousands of man-hours trying to discover what Soviet COMSEC is like. Despite all-source research dating back more than 30 years, the incidence of *any* unclassified statements by the Soviets on any aspect of their COMSEC program is so trivial as to be virtually non-existent. In other words, the Soviets protect (classify) all information about their cryptography and associated communications security measures.

~~(C)~~ The effect of this stone wall has been either to greatly delay U.S. ability to exploit some Soviet communications or to frustrate it altogether.

~~(C)~~ Viewed as an element of economic warfare, we are losing hands down as we expend enormous resources to acquire the same kind of information from the Soviets that we give them free - i.e., without classification.

~~(C)~~ Clearly, the Soviet's classification program costs them something, just as ours costs us. But, they have a cost advantage because they still operate in an essentially closed society with a well-established security infrastructure and with many of their officials already well attuned psychologically to the concept of secrecy.

~~(C)~~ Where we do classify, our tangible costs can be measured in lessened program efficiency and timeliness, and in the cost of the security barriers we then need to build around the information or material. The major intangible penalty is still asserted to be the "net loss" to COMSEC when classification inhibits system use.

~~(S)~~ The optimum attack on any cryptosystem (if you can hack it) is cryptanalytic - you need only operate on cipher text; your risk is low or non-existent unless you have to position yourself dangerously to perform the interception. You don't need to steal keys or penetrate cryptocenters or subvert people and, if you succeed, the return on investment is likely to be rich - all the secrets committed to the cryptosystem in question.

[Redacted]

~~(S)~~ Accordingly, a first line of defense has to be to protect our cryptologies (and our own diagnoses thereof) for as long as we can, regardless of our sense of the inevitability of eventual compromise.

[Redacted]

~~(S-CEO)~~ The "SIGINT" argument for protecting our cryptologies is well known - the COMSEC arguments much less so, despite their reiteration for some decades:

- With the exception of true one-time systems, none of our logics is theoretically and provably immune to cryptanalysis - the "approved" ones have simply been shown to adequately resist whatever kinds of crypto-mathematical attacks we, with our finite resources and brains, have been able to think up. We are by no means certain that the Soviet equivalent of A Group can do no better. But no attack is likely to be successful - and certainly cannot be optimized - without preliminary diagnostics - discovery of how it works.

- Systems which have no known cryptanalytic vulnerabilities may still be exploited if, and usually only if, their keying materials have been acquired by the opposition or if their TEMPEST characteristics permit it. In either of these contingencies, however, the logic, the machine itself, or both may be required for exploitation to be successful.

~~(C)~~ Because the thrust for unclassified when unkeyed equipments is lying fallow at the moment, all of the above may seem like beating a dead horse as far as our mainline equipments are concerned. But the matter will assuredly rise again.

~~(C)~~ In any event, most people in S are pretty well sensitized and/or resigned to the need for protecting logics and precise information about their strengths and weaknesses. However, that is not the case with

large batches of peripheral information about how we obtain communications system security. We tend to play fast and loose with information about alarm structures, about "TRANSEC" features, depth protection, anti-jam protection, cryptoperiods, keying techniques, testing, financial and logistics arrangements, parts catalogs, plans, schedules, operating instructions, physical safeguards, and usage doctrine in general.

(U) Attempting to protect some of this data is sometimes viewed as hopeless or useless, either because it becomes self-evident the instant a given system hits the street or because it has leaked into the public domain over the years or decades.

~~(C)~~ But beware arguments for declassification on grounds that the information - in bits and pieces - has already been published in unclassified form. Hostile intelligence is not ubiquitous, and we ought not to be compiling "unclassified" data for him, especially when blessed by our rather exceptional stamp of authenticity. And it would be well to remember that our classification of materials on the basis of their aggregate intelligence value still carries weight, despite the discomfiture when people ask which paragraph, which sentence, which word?

(U) But decisions to declassify anything about a new (or old) system should be made case by case, and at least as much thought should go into the whys of declassification as to the whys of classification. I don't think the burden of proof should lie with either the "classifier" or the "declassifier."

(U) In the final analysis, the "classifier" has only two arguments going for him - enhanced security and/or enhanced US SIGINT operations. The "declassifier" likewise has few bottom lines - enhanced COMSEC operations and - often - cost savings. The trouble is, there's usually *some* merit on both sides and, as apples and pears are involved, the "decision" is usually subjective and contentious.

~~(C)~~ The further trouble is the tendency of both "sides" to throw up smokescreens in the form of specious argument or unsupported assertions - emotionalizing the whole process:

~~(C)~~ COMSEC and SIGINT "classifiers" are quite capable of asserting irreparable harm where little or none exists in the real world - past insistence on patent secrecy for trivial devices being a case in point.

~~(C)~~ Likewise, in the case of the declassifiers - e.g., a tactical voice security advocate claiming the VINSON and PARKHILL programs would collapse if we insisted on their classification.

~~(C-CCO)~~ Perhaps, however, the biggest single shortcoming among people in S deciding on (de)classification of information stems from far too hazy a perception of how the SIGINT world - any SIGINT world - operates, and the practical difficulty that world encounters in acquiring all the data they need to target and exploit a given communication system. The process is expensive and complex, and entails well-defined steps of collection, forwarding, processing, analysis, and reporting.

~~(C)~~ Before committing assets to an attack, they need to know not just the cryptosystem, but the associated communications, the nature of the underlying traffic, deployment plans - where, when, who, how many. So the data that is valuable to them includes:

- The size of the program
 - How much are we spending on it
 - How many copies will we build
- Who the users are
- Where they will be located
- Communications platforms and frequencies
- Deployment schedules, TechEvals, OpEvals, IOC's etc.

~~(S)~~ Given all that, and the cryptologic, they can begin to get down to the serious work of deploying collection assets, adjusting targetting priorities, massing the people and equipment at home or in the field to carry out attack. That may take *years*. Thus, in short, the more advance knowledge of future crypto-system deployments they have, the better they can plan and schedule their attack. Were we ever to field a major cryptosystem with complete surprise (we never have), we might well be home free for some years even if that system had some fatal flaw of which we were unaware.

~~(C-CCO)~~ So, one root question we need to ask ourselves when we are trying to decide whether something need be classified or not is: "What would be the value of the information if I were part of a hostile SIGINT organization - any such organization?" "Will its protection block or delay potential efforts against us?" A correlative question - equally difficult for COMSEC people to answer - is: "will it be useful to an actual or potential US SIGINT target by showing that target something it can use to improve its own COMSEC

equipment or procedures?" "What would our own SIGINT people give for comparable information about targetted foreign cryptography?" A trap to avoid in attempting that answer is conjuring up only the Soviet Union as the "target" in question. Clearly, there are categories of information which would be of little use to them because of the level of sophistication they have already achieved in their own cryptography, but could be of extreme value to other countries.



~~(C)~~ All this activity culminated in our abandonment, at least for now, of the commitment to make most tactical equipment unclassified. Our announcement to that effect caused some grumbling among our customers, but not the brouhaha we had anticipated.

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PUBLIC CRYPTOGRAPHY—SOME CAUSES & CONSEQUENCES

(U) This strange term remains imperfectly defined at this writing. It seems to relate to all of the following:

- Commercially designed cryptosystems available to the general public.
- Government-designed (or endorsed) cryptosystems made similarly available.
- Cryptographic schemes and cryptanalytic treatises published in open literature by academicians and others interested in the subject.

~~(S)~~ While commercial equipment has been around for many decades, their quantity and variety was relatively small. Most were manufactured overseas - particularly in Switzerland, and no huge market existed for them after World War II because many Governments (like our own) began increasingly to use systems exclusively of their own design and under their own control. Similarly, the amount of published literature on cryptography, and particularly on sophisticated cryptanalytic ideas was sparse. In the U.S., the Government (specifically, NSA) enjoyed a near-monopoly on the subject by the early '50's. That persisted until about 1970, when a dramatic change occurred.

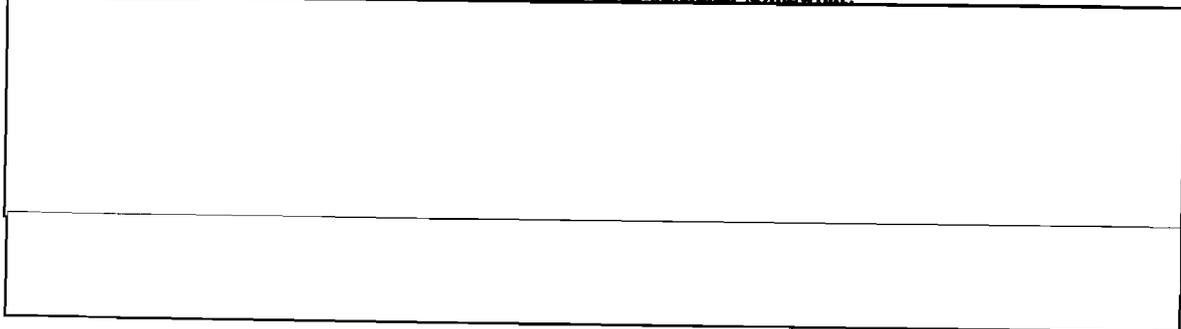
~~(S)~~ A handful of U.S. companies interested in computers, in communications, or in electronics began to perceive a market for electronic crypto-equipments. A few other American companies began building crypto-equipment in competition with the Swiss and others in Europe, supplying devices to some Governments in Africa, South America, and the Middle East and to a few major corporations - notably some oil companies seeking to protect vital industrial secrets.

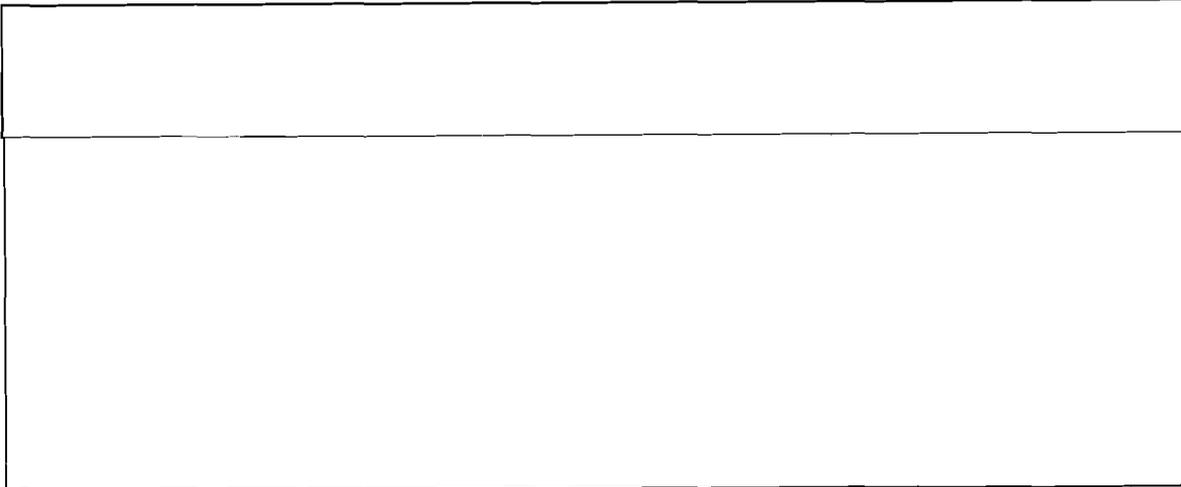
(U) At about the same time, the question of computer security, which had been on the back burner since the late 50's, began to get a great deal of attention from computer manufacturers themselves and from some of their customers. Computer fraud had become more common, and its impact, particularly on the banking world, became significant.

(U) In 1974, the Privacy Act (P.L. 93-539) was passed, imposing a legal obligation on Government Departments and Agencies to protect the information held on private citizens - notably in computer banks. Since data was increasingly being communicated among computers, the need for some means to secure these transmissions became evident. Thus, the perception of a need for encryption arose in the public sector.

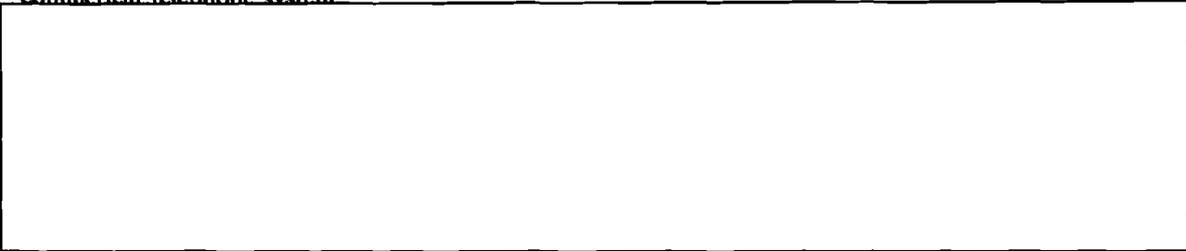
(U) The Department of Commerce has an element charged with improving the utilization and management of computers and ADP systems in the Government. They, especially, perceived a requirement for commercial sources for cryptography to protect Government computer communications and, correlatively, the need for an Encryption Standard applicable to any system offered to Government against which commercial vendors could design security devices. This Standard, the Data Encryption Standard (DES), was published by the National Bureau of Standards as Federal Information Processing Standard No. 46 in January, 1977.

(U) The process involved solicitation for proposals for such a "standard" encryption process or algorithm and two public symposia were held by NBS to discuss the merits of the winning submission (IBM's). A small storm of controversy erupted when some academicians said it wasn't good enough, and implied it had been deliberately weakened so that the Government could break it. Heretofore, in the COMSEC business, publicity of any kind - much less adverse publicity - was rare, and we were not happy. However, a Congressional investigation exonerated NSA and the issue subsided somewhat.





~~(C)~~ By this time, we had bitten the bullet, deciding to seek a generic COMSEC solution. This was a decision of enormous consequence for us. The notion of injecting Communications Security into the commercial world in a big way was unprecedented, with serious policy, political, and technical implications for all involved. Principal players became ourselves, the telephone companies, the White House, DCA, the now defunct Office of Telecommunications Policy in OMB, FCC and, ultimately many users of the commercial telephone system



~~(C)~~ The doctrinal problems were large and intractable because they involved the provision of cryptography in unclassified environments where many of our traditional physical security measures were thought to be inapplicable. How would the crypto-equipments be protected? How to protect the keys? How do you effect key distribution with no secure delivery infrastructure such as we enjoy in the Government COMSEC world? Problems of this kind led to a campaign to use the DES - the only unclassified, Government-approved cryptosystem available, thus solving the physical security problem insofar as the crypto-equipment itself was concerned. The root difficulty with this proposal from the security analysts' viewpoint lay in the fact that the DES algorithm was originally designed and endorsed exclusively for the protection of unclassified data, fundamentally to insure privacy, and without a SIGINT adversary with the power of the Soviet Union having been postulated as a likely attacker. Accordingly, the system was not designed to meet our high grade standards and we were not interested in educating the world at large in the best we can do.

~~(S)~~ Nonetheless, the system is very strong; has stood up to our continuing analysis, and we still see no solution to it short of a brute force exhaustion of all its 2^{56} variables. It is good enough, in fact, to have caused our Director to endorse it not only for its original computer privacy purposes, but for selected classified traffic as well. Cynics, however, still ask "Are we breaking it?" The answer is no. But could we? The answer is "I don't know; if I did I wouldn't tell you." And there's a good reason for this diffidence. A "No" answer sets an upper limit on our analytic power. A "Yes" answer, a lower limit. Both of those limits are important secrets because of the insights the information would provide to opponents on the security of their own systems.

~~(C)~~ The event with the most far-reaching consequences which stemmed in part from our having grabbed this tiger by the tail was the re-organization of the COMSEC effort at the National level. Historically, NSA had been the *de facto* and *de jure* National Authority for all Government cryptographic matters - a position

established by sundry Executive Orders, Directives, "charter" documents and the like reaching back to 1953. But, by mid-1976, attacks on us by a small but vocal contingent of Academe had become bitter. Some elements of the National Science Foundation which underwrote much of the cryptographic work done in the private sector joined in the beginnings of the adversarial relationship vis a vis NSA.

~~(C)~~ A fundamental challenge related to the *propriety* of an "intelligence" organization having jurisdiction over the privacy of citizens in the post-Watergate climate. In short, could we be trusted? An early action of the Carter Administration, therefore, was to issue a Policy Review Memorandum (PRM 21), to examine this issue and recommend a course of action. The result - 11 months later (Nov '77) - was a Presidential Directive (PD 24) effecting a basic realignment of roles and missions in Government for COMSEC and for something different called "Telecommunications Protection."

~~(C)~~ The Secretary of Defense remained the Executive Agent for Communications Security, but with COMSEC now defined to relate only to the protection of classified information and *other information related to national security*. A new Executive Agent, the Secretary of Commerce, became responsible for "Telecommunications Protection," defined to encompass information *not related to national security*. In both cases, the threat was defined to be exclusively "foreign adversaries" and nobody was charged with "domestic" threat - e.g., those engaged in computer fraud, industrial espionage, drug smugglers, terrorists, and the like who may be exploiting communications.

~~(C)~~ So, the split-out of roles and missions did not relate in any direct way to the kind of cryptography or other protective measures that may be used, nor to the specific customers to be served by one Executive Agent or the other, nor to the specific communications means in question nor, finally, to the nature of the opposition. It relates only to the underlying nature of the information to be secured (protected). For the past two years or more, we and the Department of Commerce have been trying to sort it out. Not the least of the difficulties is that many communications systems carry a mix of security-related and non-security related information - notably, of course, those of the telephone companies. So who's in charge?

~~(C)~~ While these events gathered steam, the HAMPER program faltered because of uncertainties on who was charged with, responsible for, authorized to, or capable of moving forward. Big money was involved, and we didn't know who should budget for it. Should the common carriers pay for it themselves, or its customers? Or the government? It is, after all, a security service that most may not want or perceive a need for.

~~(C)~~ A handful of people from the now defunct Office of Telecommunications Policy (OTP) were transferred to a new organization within the Department of Commerce (DoC) to form the nucleus of an Agency charged to implement their part of PD-24. The new Agency is called the National Telecommunications and Information Agency (NTIA) and they are the people with whom we deal daily in trying to carry out our obviously overlapping missions. A few of our former colleagues joined that Agency to help them acquire the technical competence to deal with cryptographic questions, system selection, application, and the like. We are travelling a rocky road in these mutual endeavors because, quite apart from the potential for jurisdictional dispute, we have philosophically different orientations. By and large, most people in both the COMSEC and SIGINT organizations in NSA believe that we can accomplish our missions more effectively in considerable secrecy because it helps us to conceal our strengths and weaknesses and to achieve technological surprise. DoC, on the other hand, is in business, in part, to encourage private enterprise, to maximize commercial markets at home and abroad, and to exploit the products of our own Industry for use in Government rather than having the Government compete with Industry - and this does not exclude cryptography.

~~(C)~~ While, in DoD, Technology Transfer is viewed largely as a security issue with concerns oriented towards export control for critical technologies, Commerce is interested in the infusion of our own industry with technologies now controlled by the government. They need, therefore, to maximize the declassification of information relating to cryptography. Their in-house resources remain meager, so they are turning to commercial research organizations to develop cryptographic expertise. Since these contracts are usually unclassified, and we fear the consequences of publications of what the best private sector brains may have to offer, there is some continuing tension between us.

~~(C)~~ Through all this controversy, and notwithstanding our security concerns (some will read "paranoia"), there is a very strong motivation among us for cooperation with DoC, with Industry, and with the Academic

community to get the Government's business done. Clearly, because of that near-monopoly I spoke of, we have a head start in NSA on cryptographic matters. Just as clearly, we have no monopoly on brains nor on manufacturing innovation and ingenuity. Potential security losses may well be off-set by what a motivated commercial world and interested Academe might offer to the Government for its own use. There is a school of thought that believes that various commercial offerings - notably those which may embody the DES - may fill a gap in our cryptographic inventory which our own systems cannot fill because of their design against high and costly standards and tough military specifications, their protection requirements, and the protracted periods of time they generally take to produce. Note, for example, that after all these years, a significant majority of military voice communications and almost all non-military Governmental voice communications remain unsecured. Inexpensive and quickly available commercial voice equipments might move into this vacuum and - even though they may generally offer less security - we might enjoy a net gain because otherwise, for many years to come, those communications will be there for the taking, essentially free of cost to an opponent. This argument does not mollify the conservative, however.

(U) At this writing, some uncertainty remains as to how large the market for commercial devices, notably DES, may be. There seems to be a consensus that they may be applied in considerable quantity to protect or authenticate the contents of messages in support of financial transactions, and most especially in the field called Electronics Fund Transfer (EFT) because of demonstrated vulnerability to costly fraud.

(U) But, although a Government endorsed technique has now been on the street for a number of years, there has as yet been no rush to acquire equipments in quantity. This may be due, in part, to significantly lower perceptions of threat on the part of prospective customers than projected by ourselves and others. It may also stem, in part, from the slowness with which supporting Government standards and guidelines are being published (for Interoperability, Security Requirements, etc.)

(U) In any event, production and marketing of equipment by U.S. commercial vendors is not our biggest problem with public cryptography because there are various Government controls on such equipment - particularly, export controls - and Industry itself is usually disinterested in publishing the cryptanalytic aspects of their research in any detail. The central issue that continues to fester is encapsulated in the phrase: "Academic Freedom versus National Security."

(U) Our Director has made a number of overtures to various academic forums and individuals in an effort to de-fuse this issue, but has stuck to his guns with the statement that unrestrained academic research and publication of results can adversely affect National Security. While a few academicians have been sympathetic, the more usual reaction - at least that reaching the press - has been negative.

~~(C)~~ The principal reason that there is an NSA consensus that unrestrained academic work has a potential for harm to our mission is because, if first-class U.S. mathematicians, computer scientists, and engineers begin to probe deeply into cryptology, and especially into cryptanalytics, they are likely to educate U.S. SIGINT target countries who may react with improved COMSEC. Less likely, but possible, is their potential for discovering and publishing analytic techniques that might put some U.S. cryptosystems in some jeopardy.

(U) The academicians' arguments focus on absolute freedom to research and publish what they please, a rejection of any stifling of intellectual pursuit, and concerns for the chilling effect of any requests for restraint. Their views are bolstered by the real difficulty in differentiating various kinds of mathematical research from "crypto-mathematics" - notably in the burgeoning mathematical field of Computational Complexity, often seeking solutions to difficult computational problems not unlike those posed by good cryptosystems.

~~(C)~~ As a practical matter, Government "leverage," if any, is rather limited. We have made some half-hearted attempts to draw an analogy between our concerns for cryptology with those for private research and development in the nuclear weapons field which led to the Atomic Energy Act that does - at least in theory - constrain open work in that field. But there is no comparable public perception of clear and present danger in the case of cryptology and, despite the "law," academicians have sanctioned research revelatory of atomic secrets including publications on how to build an atomic bomb.

~~(C)~~ Another wedge, which as yet has not been driven with any appreciable force, is the fact that - overwhelmingly - the money underwriting serious unclassified academic research in cryptography comes from the Government itself. Among them are the National Science Foundation (NSF), the Office of Naval

Research (ONR) and the Defense Advanced Research Projects Agency (DARPA). NSA supplies a little itself. The wedge is blunted because Government officials administering grants from most of these institutions have been drawn largely from the academic community who believe strongly in the value of research performed outside Government, and are sympathetic to concerns about abridgement of Academic Freedom.

~~(C)~~ In the long run, balancing out our mutual concerns will probably depend more on the good will of influential sections of the Academic Community itself than on legislative, monetary or other control over cryptographic research in the private sector. It turns out that at least some governing bodies in various colleges and universities seem more ready to recognize some academic responsibility with respect to national security concerns than do many individual "young Turk" professors or their collective spokesmen who see Academic Freedom in First Amendment terms as an absolute. A good deal of the Director's quiet work on the matter appears to be oriented towards constructive dialog with responsible officials and groups.

~~(S)~~ I have dwelt on the matter of public cryptography at some length because it portends some radical changes in our relationship with the public sector - more openness, dialog, controversy, and debate. Obviously, our conventional shield of secrecy is undergoing some perforation. In contrast, it might be worth noting that we have yet to see a single unclassified document from the USSR on their cryptography - not one word. (As a result, we spend small fortunes acquiring data comparable to that which realities suggest we must continue to cough up for free.)

(U) Nonetheless, I believe we can identify and continue to protect our most vital interests - our "core secrets" - and, meanwhile, dialog with intelligent people - even "opponents" - will surely expand our own knowledge and perspective.

~~(C)~~ A more tangible outgrowth of public cryptography could be the infusion of commercial equipment in Government for the first time since World War II. As noted earlier, the votes are not yet in on how prevalent that may be; but it bodes new sets of problems in standards, doctrine, maintenance, protection, configuration control, cost benefit analyses, and secrecy.



(U) How do we offer a reasonable COMSEC education to U.S. users in unclassified environments without educating the world?

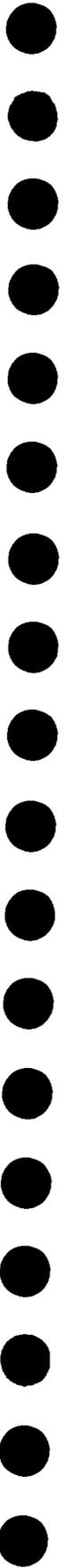
~~(C)~~ How do we underwrite, endorse, certify, approve or otherwise sanction products in the abstract when their real security potential may well lie in how they are applied in a systems complex, not just on a good algorithm? Or how, alternatively, do we find the resources required to assess dozens of different devices in hundreds of different applications?

(U) We are currently wrestling with all these questions; but most of them will be incompletely answered for a long time. It may be useful for you to keep them in mind as you get involved with public cryptography downstream.

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PKC

—(C)—One of the more interesting outgrowths of the burgeoning interest in cryptography in the private sector was the “invention” of a concept called “Public Key Cryptography” (PKC). All conventional cryptography requires the pre-positioning of shared keys with each communicant. The logistics for the manufacturing and delivery of those keys keeps S3 in business and forces users to maintain a large secure crypto-distribution system. (Remote keying eases but does not eliminate the problem.) The thought was, cryptography would be revolutionized if a system could be devised in which people could communicate securely without prior exchange of keys.

(U) The main idea that came forward was an effort to capitalize on the fact that some mathematical functions are easy to carry out in one “direction,” but difficult or impossible to reverse. A classic example of these so-called one-way functions is the phenomenon that it is not hard to multiply two very large prime numbers together, but given only their product, no elegant way has been put forward for determining what the two original numbers were.

(U) So the original numbers could be considered to be part of one man’s secret “key:” their product could be published; an encryption algorithm could be specified operating on that product which could not be efficiently decrypted without knowledge of the “key”; and all messages addressed to that person would be encrypted by that algorithm.



(U) It was an interesting mathematical puzzle, first put forward centuries ago, but with no great incentives for its solution beyond the satisfaction of intellectual curiosity, no perceived commercial applications, and so on. So there was no evidence of a great many brains having worked the problem over the years; nor did we go all out against it because, apart from theoretical doubts, there were other drawbacks.

—(C)—The most obvious - although perhaps not the most important - was the fact that the encrypter himself could never decrypt his own message - he would be using the cryptosystem of the recipient who was the only one holding the secret decrypting key - he would have no means to verify its accuracy or correct an error. More or less elaborate protocols involving hand-shaking between the communications were put forward to get around this difficulty - usually entailing the receiver having to re-encrypt the received message in the sender’s key and asking if that was right. A clumsy business.

—(C)—Next, each user would have to keep his primes absolutely secret, forcing on each some of the secure storage and control problems inherent within conventional schemes. Known (or unknown) loss would compromise all of his previously received messages. To get around that, relatively frequent change would be necessary. This would move him towards the conventions of keying material supersession; generation and selection of suitable primes and their products, and their republication to all potential correspondents.

—(C)—Next was the matter of efficiency. The “key” would have to be on the order of 1000 bits long to make factorization difficult (or impossible?). Inherent in the scheme is the requirement to use all of that key for any message, however short. Further, a single garble renders the entire message unintelligible.

(U) In the more detailed schemes outlined so far, generation and manipulation of very large numbers is required, including raising them to some as yet undetermined power - but clearly more than just squaring them - and this leads to great complexity in any real implementation of the idea.

—(C)—Finally, there is the problem of spoofability. Anyone can send you a message in your key which you must either accept as valid or authenticate somehow. If I inject myself in your communications path, I may purport to be anybody, supply you my key, shake hands like a legitimate originator and lead you down various garden paths indefinitely.

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(S) So we are not yet prepared to accept PKC as a wave of the future. However, it continues to offer intriguing possibilities, particularly for short messages resupplying conventional keys among small user sets, and we may eventually find some use for it if we can do so without creating problems at least equal to those it is designed to solve.



COMPUTER CRYPTOGRAPHY

(S) Since most crypto-equipments these days can be viewed essentially as hard-wired special purpose computers with "programmable features" to accommodate variables, there has been considerable effort, dating at least to the early '60's, to use general purpose (GP) computers to do cryptographic functions - programming the whole process, encryption algorithm and all. The idea was particularly attractive at installations where some GP computer with excess capacity was already in place. The first operational system I recall was used to decrypt telemetry from the Navy's first position location satellite - the Transit system, in a shipboard computer, the BRN-3, implemented in 1963. Since the computer was required anyhow to carry out navigational calculations based on data received from the satellite, since it operated in a receive only mode (the sender was a conventional black box in the satellite), and since operation was "system high" (i.e., all personnel with access to any part of the computer were fully cleared for all the data being processed), no big computer security problems were involved - rather, it was a technical matter of programming cryptography efficiently into a system not originally designed to carry out such functions.

(C) Nevertheless, there has been little proliferation of computer cryptography in the ensuing years, mainly because the inherent constraints in the BRN-3 environment (excess capacity, system high operation, receive mode only, and rigorous access control) are still not prevalent. The security problems that arise when one or more of those limits disappear are difficult indeed. If, as is increasingly the case these days, the computer can be remotely accessed by various subscribers, the difficulty is greatly compounded. This is true because the vulnerability of sensitive data in a computer to inadvertent or deliberate access, extraction, pindown, disruption, tampering, misrouting, or other manipulation increases as you increase the opportunities for physical or electronic access to it. In this respect, the problem of insuring the security integrity of cryptographic information in a computer is no different than with "computer security" in general. As you no doubt know, that general problem is being assaulted on many fronts today with efforts to make "provably secure" operating systems, the development of the "security kernel" concept, kernelized virtual machines and so on. The threats are so numerous that a 247 page document ("ADP Security Design and Operating Standards", by Ryan Page) is still not definitive.

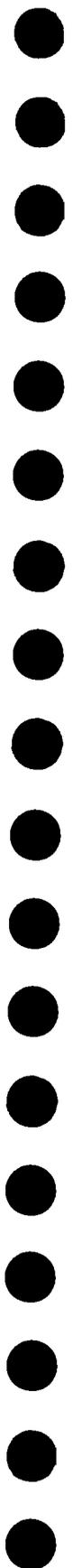
(C) Not the least of our worries with computer encryption proposals is the question of how to evaluate their security potential, how to validate large software programs such as you would need to implement, say, SAVILLE in software; and how to insure that "peripheral" changes elsewhere in the computer will not affect the integrity of the cryptography. It turns out, naturally enough, that S6 proceeds with diminishing confidence as systems become more complex, and with more and more functions not under the cryptographic designer's control which yet may affect the way the cryptography works. Control functions, timing functions, switching functions, etc., are typical examples of these "peripheral" activities that don't remain static - i.e., aren't hard-wired - and subject to change to facilitate other functions in the computer as time goes by.

(C) Two other factors have slowed the rush towards computer cryptography. The first is that most commercially available computers still have TEMPEST problems. Few meet our TEMPEST standards for crypto-equipments (KAG-30), and they are difficult to fix. The other factor is that the dedicated (special purpose) computer - an ordinary cipher machine, for example - can always carry out a single job more *efficiently* (space, speed, power consumption, and so on) than one with multiple functions.

(U) None of this means we can't do it - but we aren't there yet. And it's just possible that it's another of those waves of the future that will dissipate in the sea of time.

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(U) Or so it often seems to someone trying to whip up some enthusiasm for a change.

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TEMPEST UPDATE

—(C)—TEMPEST difficulties seem to whipsaw us more than any of the other technical security problems we have. Each time we seem to have achieved a reasonably well-balanced and managed program in NSA, other Agencies, and in the Industrial TEMPEST Program (ITP), some new class of problems arises. Better detection techniques call some of our older standards into question. New phenomena or variations of old ones are discovered. New kinds of information processors come into the inventory from the commercial world posing different suppression problems. Vulnerabilities remain easier to define than threat in most environments, and we seem to wax hot and cold on how aggressively the whole problem should be attacked.

—(S-NF)—The proliferation of Cathode Ray Tube display consoles (CRT's) is among the more recent examples to catch our attention and that of our customers. Most computers and their peripherals still come off the shelf from Industry without much TEMPEST protection built in. Customers may lay on tests after installation and if they see problems in their particular facilities, may try to screen them or, if threat perception allows, take their chances on hostile exploitation. But with CRT's, two things happened. First, they were more energetic radiators than most other information processors unless TEMPEST suppression (at greater cost) had been applied during manufacture. Second, the results of testing of an insecure device were horribly obvious. Testers, instead of having to show some skeptical administrator a bunch of meaningless pips and squiggles on a visicorder and esoteric charts on signal to noise ratios, attenuation, etc., could confront him with a photocopy of the actual face of his CRT with the displayed data fully legible, and could demonstrate instantaneous (real time) recovery of all of it from hundreds of yards away. This gets their attention.

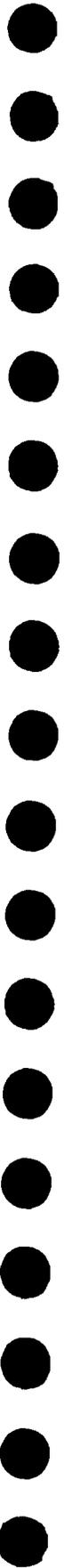
—(C)—However, as seems to be the case with many of our more dramatic demonstrations of threat or vulnerability, the impact is often short-lived, and the education process soon must start again. But, despite the apparent fluctuations in threat perception and correlative command interest, the resources in R&D and personnel committed to TEMPEST problems in NSA and the Services remains fairly consistent,

—(S)—It's fair to conclude that the problem will be with us as long as current flows, but the earlier judgment that we have it reasonably well in hand except in unusually difficult environments may have been too sanguine. We are being faced with more and more types of sophisticated information processors - including computer-based systems - and these are proliferating at a greater rate than we can track. This fact, coupled with more widespread knowledge of the phenomenon, the decline in the availability of trained technical personnel for testing and corrective action in the field (some test schedules have fallen as far as two years behind), and the advent of more potent exploitation devices and techniques place us in a less than satisfactory posture.

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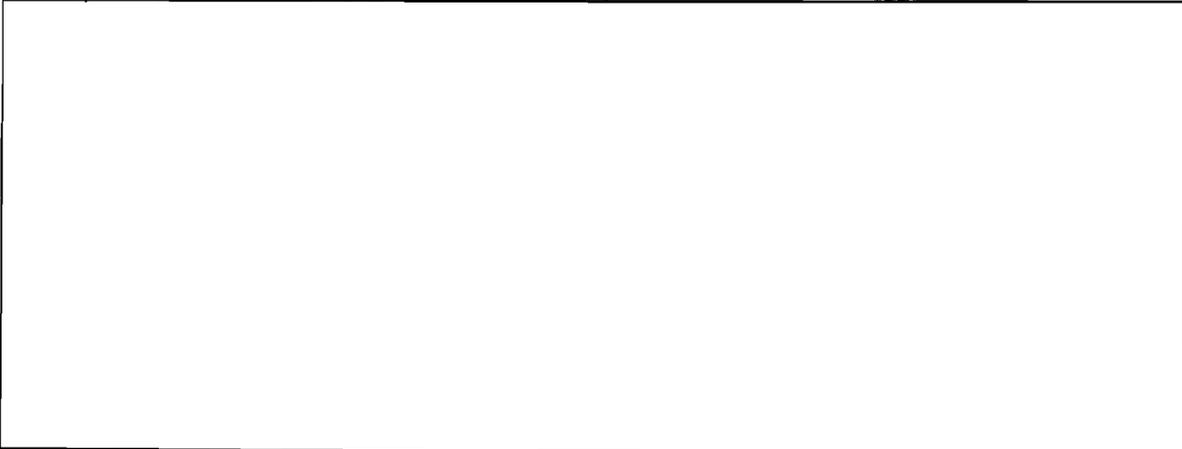


SFA REVISITED

~~(C)~~ "SFA" used to stand for "Single Failure Analysis." In the early 70's, a somewhat more elegant but less precise meaning arose - "Security Fault Analysis." It is a systematic process for examining the embodiment of a cryptologic to determine the security effect of malfunction or failure of individual components, switches, circuits, registers, gates and the like. Its purpose is to assure that any fault which would have a catastrophic effect on systems security is safeguarded against - usually through redundancy in design or some kind of alarm.

~~(C)~~ A classic example of catastrophic failure is one which allows plain language being encrypted to bypass the key generator altogether and be transmitted in the clear. Another - usually more insidious - is a failure in randomizer circuitry causing predictable or repetitive initial set-ups for a machine.

~~(S)~~ SFA had its beginnings with relatively simple electro-mechanical devices where pins might stick, switches hang up, or rotors fail to move, and no truly systemized examination for such failures was carried out or necessary. Most of those failures were not visualized and prevented during design. Rather, when they cropped up in the field and were reported, we would have to go back and retrofit. We had, for example, a case with a duplex one-time tape circuit where an operator noticed that an exact copy of his outgoing traffic was being printed, in the clear, on his receive teletypewriter. He thought a previous operator had jacked that teleprinter in to provide a monitor copy to assure accuracy of his send traffic. What had really happened was a simple failure of a Sigma Relay at the distant end of the circuit which caused the incoming messages, after decryption, to not only print out normally on his receiver but also to be shunted back, in the clear, over his send line. In another case, an on-line rotor system called GORGON seemed to be operating perfectly all day long when an operator noticed that the familiar clunking sound of moving rotors seemed to be missing. He lifted the lid to the rotor basket and discovered why. There were no rotors in it. Ordinarily, that would have caused continuous garble at the distant end, and the operator there would have sent back a BREAK to stop transmission. In this case, however, the distant end had *also* forgotten to put the rotors in, and so received perfect copy in the clear, but believed it to be decrypted text.



~~(C)~~ It worked out alright, though. For their part, the analysts began to get more precise about what constituted a critical failure. The designers meanwhile, through systematization of the process during equipment manufacture, found ways to anticipate problems and avoid some of the back-fitting which had previously been necessary. As is usually the case in our business, when security requirements conflict with cost in time and money, a fairly pragmatic trade-off is made. We have yet to build a machine deemed perfect from the security analysts' viewpoint, and I doubt we ever will. On the other hand, we've made few if any equipments against which security design overkill has not been asserted by its builders or the budget people, or both.

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NESTOR IN VIETNAM

~~(S)~~ Most US SIGINT assets in Vietnam used NESTOR heavily and successfully almost from the outset. Towards the end of the war, so did most in-country Naval forces, particularly airborne assets. In the SIGINT user's case, it was because they were already equipped when they got in country; had used it previously, knew, accepted, or circumvented its peculiarities, and, of course, because they believed their traffic required protection. In the Navy case, it was the result of Draconian measures by the Commander, Naval Forces, Vietnam (COMNAVFORV). That Admiral happened to be a COMSEC believer; so he told his pilots that if they didn't use the equipment, he'd ground them. Some didn't, and he did. There is, I understand, no comparable trauma for a fighter pilot.

(U) The story with most of the rest of the "users" was quite different, and very sad. The reasons and excuses were manifold, and a few will be treated here for what might be learned from it.

~~(C)~~ It was claimed that NESTOR reduced radio range. In an environment where communicators were only marginally able to reach one another anyhow, this was intolerable. Experiments at NSA before the equipment was deployed, and repeated investigations when these claims persisted, verified that NESTOR did not reduce range. They even showed that the system could sometimes enhance communications by holding higher voice quality (less noise) towards range limits; although when it reached the limit, loss of all intelligibility was abrupt and categorical.

~~(C)~~ Finally, our own engineers sent to Vietnam reported back: "Sorry about that, S2; the system reduces range - typically by 10% or more." And it, in fact, did. It turned out that NESTOR did not affect range only if the associated radio was perfectly tuned, "peaked," matched to the NESTOR equipment (as we naturally did here at home). In the field, maintenance personnel were neither trained nor equipped for such refinement - the test instrumentation simply did not exist there, and we had not anticipated those real world conditions when we sent it out.

~~(C)~~ In tactical air, it was claimed that the sync delay - up to 3/5 of a second of required wait between pushing to talk and ability to communicate - was intolerable when air-to-air warnings among pilots had to be instantaneous. A survey showed, by the way, that most pilots judged this time to be on the order of three seconds; so, in fact, the wait must have seemed interminable when one wanted to say "Bandit at two o'clock."

~~(C)~~ Carrier-based aircraft ultimately adopted what was called a "feet wet-feet dry" policy in which they would operate exclusively in cipher while over water, but once over land, would revert to plain language. For Air Force pilots, it was not so much of a problem. They managed to install so few equipments in their aircraft, that they were able to create few viable crypto-nets, so most of them were in clear all the time.

~~(C)~~ Navy had managed to jury-rig NESTOR (KY-28) equipment in essentially every carrier-based fighter aircraft they had. In the case of the F4 they found a nook inside the nose-gear housing, and tucked it in there. But the Air Force opted to go into a major aircraft modification program to accommodate the system, penetrating the skin and with elaborate wiring to remote the system to the cockpit. This took years. The problem was compounded because when aircraft did get in country with NESTOR's installed, they were periodically recalled to CONUS for maintenance and rehabilitation, took their NESTOR with them as part of the avionics package, and were replaced with unequipped planes.

~~(C)~~ The ground version of NESTOR (KY-8) would not run in high ambient temperature. True. And there was plenty of such temperature around in Vietnam. There was an inelegant but effective solution to that one. The equipments were draped with burlap and periodically wetted down. So much for our high technology.

~~(C)~~ There was a shortage of cables to connect NESTOR to its associated radio. This sounds like a small and easily solvable difficulty; but it turned out to be one of the biggest and most persistent we had. It stemmed from a deeper logistics problem because different organizations were responsible for fielding the various components that went into a secure tactical system. We procured the NESTOR equipment. Various Service organizations procured the various radios with which it was used; and still different organizations fabricated cables and connectors to link them up. Systems planners and implementers in Vietnam eventually

gave up and appealed to CINCPAC to orchestrate a coherent program. CINCPAC gave up and appealed to JCS (who may have done a staff study), and it was never solved.

~~(C)~~ Some NESTOR users had AM radios, some FM, and ne'er the twain would meet even though they were cooperating forces.

~~(C)~~ Over the length and breadth of South Vietnam were many cryptographically unique NESTOR nets (i.e., different key lists) to comply with doctrinal rules limiting net size because of the high vulnerability to compromise of keys in that environment. The limit started out at about 250 holders, was extended to 400, and we eventually tolerated a country-wide net for air-to-air/air-ground communications to accommodate aircraft which might show up anywhere.

~~(C)~~ The manpack version (KY-38) was too heavy - KY-38 plus PRC 77 radio, plus batteries, plus spare batteries weighed about 54 pounds. The Marines, especially, tried to overcome this, even going so far as to experiment with two-man carries, one toting the 38, the other the radio, and with a cable between them. As you might imagine, that worked none too well in the jungle, and I believe most of them decided that carrying ammunition would be more profitable for them.

~~(C)~~ NESTOR is classified, people fear its loss, careers may be in jeopardy, and it was safer to leave it home. This Unicorn - this mythical beast - was the most aggravating, persistent, elusive, and emotional doctrinal issue to come out of that war. We sent emissaries to a hundred locations. We found no qualms about associated keying materials always with the equipment, and which were almost always more highly classified than the equipment itself. We found no concern over keyed CIRCE devices issued in well over 100,000 copies; and we found another CONFIDENTIAL tactical equipment, KW-7, used with enthusiasm as far forward as they could get power. Our records show that the exact number of NESTOR equipments lost as a result of Vietnam was 1001, including a number that were abandoned when we were routed, but mostly in downed fixed wing aircraft and choppers, and in overruns of ground elements. We found no evidence of "disciplinary" action because somebody lost a NESTOR while trying to fight a war with it, nor, in fact, for any other cause. Yet, "classification inhibits use" remains a potent anti-classification argument for all crypto-equipment to this day.

~~(S)~~ The argument in the Vietnam context came as close to being put to rest as I suppose it ever will be by a major study published in 1971. By that time the matter of non-use of NESTOR had become a burning issue. Here, an expensive crash program had been undertaken by NSA to build and field 17,000 KY-28's and 38's; a bonus of \$3 million had been paid for quick delivery. The total NESTOR inventory exceeds 30,000, yet best estimates in 1970 suggested that only about one in ten of the devices was being used. A questionnaire was administered to about 800 individuals who had had some exposure to the system in SEA. It contained a dozen or so questions, all oriented towards determining why the system was not being used more heavily. Some of the more relevant findings are quoted below:

- ~~(C)~~ How do you feel that the use of tactical secure voice equipments affects the operations of your unit?
 - 1—Speeds up and improves operations
 - 2—Slows down and interferes with operations
 - 3—Has little or no affect on unit effectiveness

OGA

	Answer No. 1		Answer No. 2		Answer No. 3	
	Number of Responses	Percent of Total	Number of Responses	Percent of Total	Number of Responses	Percent of Total
Overall	463	58.5	173	22.0	152	19.2
Army	220	78.9	23	8.2	36	12.9
Navy	99	68.2	25	17.5	19	13.3
Air Force	199	37.1	118	36.8	84	26.2
Marines	25	55.6	7	15.6	13	28.9

~~(C)~~ Listed below are a number of factors which might tend to cause responsible persons to avoid taking TSV equipments into combat or simulated combat. Rank them (and any others you may wish to add) in the order of their importance to you.

A—My military career might suffer if I were judged responsible for the loss or compromise of cryptographic material.

B—The enemy might be able to recover lost equipment and keying materials and might then be able to read U.S. TSV traffic.

C—If my TSV equipment were lost at a critical time, its unavailability might reduce the operational capability of my unit.

D—The TSV my unit uses most must be *carried* into combat and is so heavy that it slows down our mobility.

E—Other (Specify)

	A	B	C	D	E	
Overall	45	266	87	63	29	Figures shown are first choices
Army	24	113	43	47	5	
Navy	7	31	19	0	3	
Air Force	13	104	21	3	10	
Marines	1	18	4	13	1	

(C) If you use TSV equipment in combat, simulated combat, or other hazardous circumstances, does your concern about its possible loss or compromise restrict its operational use or usefulness?

1—Yes, to a considerable degree

2—To some moderate degree but not significantly

3—No

	Answer No. 1		Answer No. 2		Answer No. 3	
	Number of Responses	Percent of Total	Number of Responses	Percent of Total	Number of Responses	Percent of Total
Overall	46	7.7	97	16.3	451	75.9
Army	30	13.6	57	25.9	133	60.5
Navy	2	2.6	10	13.0	65	84.4
Air Force	7	2.9	2	0.8	229	96.2
Marines	7	17.9	8	20.5	24	61.5

(C) Listed below are a number of possible operational disadvantages which have been raised with regard to the use of TSV communication and identify their importance to you.

A—Inability of TSV-equipped stations to communicate in cipher with all desired stations.

B—Occasional interruption of communication due to loss of synchronism between the transmitting and receiving stations.

C—The time delay required to synchronize the sending and receiving crypto-equipments is intolerable in some type of military activity.

D—The size and weight of the TSV equipments and their power supplies is prohibitive in some situations.

E—The application of TSV equipment to UHF, VHF-AM, and/or VHF-FM tactical radio circuits/nets reduces seriously the effective ranges.

F—An unacceptable level of maintenance problems are associated with the operation of TSV equipments.

G—TSV equipment is not reliable in critical situations.

H—Unacceptable physical security restrictions are associated with the use of TSV equipments in the field.

I—Other (Specify)

	A	B	C	D	E	F	G	H	I
Overall	223	115	46	54	31	18	28	13	12
Army	72	43	7	39	10	11	1	5	2
Navy	41	31	6	1	7	3	7	3	4
Air Force	101	35	30	4	14	4	20	4	4
Marines	9	6	3	10	0	0	0	1	2

~~(C)~~ From the NESTOR experience, and the antithetical experience with ORESTES and other systems in much the same environments, it might be concluded that the overriding criteria for the acceptance or failure of our equipment offerings are whether there is a perceived need and whether they do what they're supposed to do - they work - reasonably well without inhibiting operations.

EMERGENCY DESTRUCTION OF CRYPTO-EQUIPMENT

~~(C)~~ Except in a tiny number of locations where the user can afford the luxury of large powerful disintegrators that chew crypto-components into little pieces, we remain dependent on World War II pyrotechnic technology to get rid of crypto-equipments in a hurry in an emergency. Meanwhile, the environments into which the equipments are now being deployed are increasingly hazardous in peace time and in war. Further, when we ruggedize hardware we aren't kidding, having fielded some of the most indestructible boxes in the world. Some seem at least on a par with flight recorders that survive the most catastrophic of crashes.

~~(C)~~ A crashed helicopter in Vietnam caught fire and reduced itself to not much more than slag. Its NESTOR equipment was fished out, cleaned up, and ran perfectly. More recently, a telemetry encryption equipment (KG-66) on a missile shot at White Sands ran perfectly after being dug out of the 8 foot hole created at impact.

~~(C)~~ Chip technology compounds the problem. The chips are so small that they'll often filter through a disintegrator unscathed. Conventional pyrotechnics don't help because their melting temperature is typically 2800° F.

~~(S-NF)~~ Meanwhile, the new environment? When Volume I was written, the only case in US history of the invasion of an Embassy was by mob in Taipeh in 1957. There were no destruct facilities and, had there been, then as now, the whole building would have gone up in smoke had pyrotechnics been used. So - again then as now - reliance was on the vault. Since the mob could not penetrate its big steel door, they knocked a hole in the adjacent wall, stormed into the crypto-center, and scaled rotor and other cryptomaterial down to the crowd below. About 50 of the 100 or so rotors were not seen again. Since those days, no less than 32 (counting MAAG, the total is near 50) U.S. facilities (embassies, legations, missions) containing crypto-equipment have come under attack, 13 of them during the 6 Day War in the Middle East, 7 more in Iran during the revolution, another incident with the re-invasion of the Embassy when the hostages were taken, other assaults in Islamabad and Tripoli, and an attempt on our Embassy in Beirut.

~~(S-NF)~~ In all, in the first Iranian crisis, 7 different types of crypto-equipment were jeopardized, totalling some 65 pieces of hardware. Precautionary evacuation and emergency destruction efforts ranged from total and sometimes spectacular success, to complete failure in one installation where two types of equipment had to be left up, keyed, running, and intact. It became clear that our destruct capabilities were inadequate or useless where we had little warning, and hazardous at best even where warning or a good vault offered time to carry out the procedures. Fire could lead to self-immolation in the vaults; shredders and disintegrators depended sometimes on outside power which was cut off; and smashing of equipments could render them inoperative, but not prevent the reconstruction of their circuitry.

~~(S)~~ Correlatively, our traditional policy for limiting the use of crypto-equipments in "high-risk" environments was quite evidently wanting. That policy generally called for deployment of our oldest, least sensitive, and usually, least efficient systems in such environments. The effect was to deny people in the field good equipment in crisis, just when they needed it most. This was particularly true of secure voice equipment to report events, and effect command and control when installations were under attack.

~~(C)~~ What seems needed is some push-button capability to zap the equipment, literally at the last moment, allowing secure communications until the facility must be abandoned, and not dangerous to the button pusher.

~~(S)~~ The most successful use of pyrotechnics (thermate slabs, thermite grenades, and sodium nitrate barrels) in Teheran occurred at the major Army Communications Center there. It had a number of crypto-equipments, but also served as a depot for pyrotechnic materials for the whole area. They piled all of their classified cryptomaterial in a shed; covered them with their pyrotechnic material (some 300 devices), lit off the whole enchilada, and took off. The result was probably the largest single conflagration during the entire revolution. Observers reported seeing flames shooting hundreds of feet into the air from posts several miles away. The building was, of course, consumed, and we assume only a slag pile remains. (At this writing, about 15 months later, no American has been back.)

—(S)—Despite all of the above, we have not been altogether inert on the matter of emergency destruction over the past decade or so. Each catastrophe seems to have stimulated at least a brief burst of effort to find a way. When the Pueblo was captured, we found that our best laid emergency destruction plans had gone awry. There was a shredder and an incinerator on board, and a few axes and sledges. In those days, Navy ships were not permitted to carry pyrotechnic destructors because of their fire hazard. Considerable reliance was placed on jettisoning material; but in the Pueblo case, the crew could not get to the side without being machine-gunned. We had, in any event, become increasingly skeptical of jettisoning as a viable way to prevent the recovery of equipment as various submersibles attained greater and greater depths. We also found to our astonishment that some of the electronic crypto-equipments built in the fifties (and sixties) float.

—(S)—Our first major customer for a safe and reliable means for emergency destruction on shipboard was, as you might expect, another intelligence collector: [redacted] S2 was allowed to fabricate some boxes (on a not-to-interfere with COMSEC work basis) which would incinerate material while containing the heat and flame. Some research was carried out, again under S2 aegis, to build or modify ordinary safes to destroy their own contents. Work came to a virtual halt, however, when a disgruntled contractor whose proposal had been turned down raised an unholy stink with our Director, senior officials in the Defense Department, and sundry Congressmen. (Congressional inquiries, we have discovered, can sometimes have a chilling effect.)

—(C)—The upshot was that NSA and DoD decided that the *general* problem of destroying classified materials was not NSA's business - particularly with respect to the destruction of ordinary classified documents. We were directed to confine ourselves exclusively to techniques uniquely useful in the cryptographic business. The trouble was that there was no other Government Agency prepared to accept such a role. The Army Chemical Corps had provided the original pyrotechnic approaches to destruction but, as noted, had not done much since World War II except, at NSA behest, the development of the sodium nitrate in a barrel or hole-in-the-ground approach. There had been an agency created in the Department of Defense in its early days called the Physical Security Equipment Agency. It was an assemblage of physicists, chemists, and engineers with little security background and apparently, few practical ideas. They were abolished in December 1976, with no re-assignment of their functions.

—(C)—So, in 1976, DoD accepted the overall responsibility for destruction methodology, and assigned the Navy as Executive Agent to do the necessary research and development. As usual, they were underfunded and understaffed, and have been progressing very slowly. We, meanwhile, keep not much more than a manyear or two engaged in the special problems of crypto-equipment destruction. With our increasing reliance on micro-circuitry, someone had the idea of planting tiny, non-violent shaped charges in critical junctures in our circuits that could be triggered by the application of external voltage. The project became known as LOPPER, and R1 was charged to pursue it. The original equipment targetted for incorporation of the technique was VINSON. But, it would cost more, might delay the program and, again, did we really need it? So, R1 had developed the technique to the point of feasibility demonstration models; tests were run on circuit boards, were successful, and we stopped.

—(C)—We were damned again by the perception that this was a solution looking for a problem - exactly the same inhibitor which has slowed or killed nearly every new departure that costs something for which there is no *universally* recognized need. We (proponents of the desirability of protecting our hardware as best we can for as long as we can) had done it to ourselves when we began letting people know, as early as 1950, that the key's the thing; all those contrary arguments in the direction on classification notwithstanding. One set of curmudgeons in our business can insist that security is not free, that we are in the communications security not the communications economy business, while another set, with equal force, can state that the too-high security standards or demands are pricing us out of the market, leaving our tender communications altogether naked to the world.

(U) I suggest that newcomers to the business not jump on board whichever side of this controversy your viscera may first direct. Rather, take the other side - whichever it is - and go through the exercise of building its defense. You are likely to be surprised at how elaborate and involuted the arguments become either way and might lead you to my personal conclusion that the best way to achieve a net gain in our resistance to communications compromise is through compromise. Still, it seems that once in a while one

~~CONFIDENTIAL~~

ought stand on principle - as a matter of principle! - and hang tough where truly vital interests are concerned.

~~(C)~~ So, LOPPER came a-cropper, at least for a time. The "compromise" solution was put forward: if we can't afford to implant this technology in the whole product line, can't we at least build a limited quantity of circuit boards with the capability for deployment to high-risk facilities? The answer was no: small quantity production is far too expensive; you can't amortize the R&D and product costs. Turns out that there is a useful rule of thumb for most of our product line: unit cost drops 15-20% for each doubling of the number of procured.

(U) At the moment, we are in low-key pursuit of a variation of the LOPPER approach for some future systems. It involves burying a resistor in the chip substrates which will incinerate micro-circuitry with the application of external voltage. We'll see.

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POSTSCRIPT ON DESTRUCTION—DAMAGE ASSESSMENTS

~~(C)~~ When major potential losses of cryptomaterial occur, damage assessments are called for - usually in a hurry; and particularly if the possibly compromising incident hits the press. Often, we will have 24 hours or less to make some kind of interim assessment of what may have been lost, in what quantity, with what probability, and with what impact on national security.

~~(C)~~ Often in this hectic process, we start out with little more than what's in the newspapers but, because of our access to the records of the crypto-accounts involved, we are usually able to build a pretty good inventory of the materials involved within a few hours and, sometimes have information on the destruction capabilities at the site(s) involved. In first reports, what we rarely get is an accurate picture of the degree of the destruction actually achieved; so our initial assessments are invariable iffy.

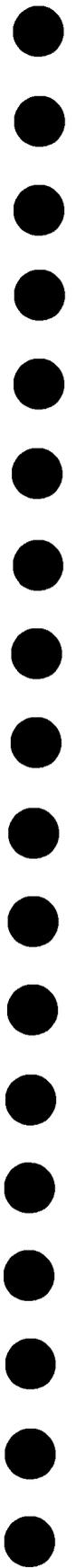
~~(C)~~ A principal lesson we have learned in formulating these assessments is patience - sometimes waiting many months before we "close" the case, meanwhile interviewing witnesses to or participants in the event, visiting the scene if we can get there, performing laboratory analyses of recovered residues of the destruction effort, and so on, before making a definitive declaration of compromise or no compromise, as the case may be.

~~(C)~~ A second lesson has been that our first gut reactions have usually been wrong, erring equally on the optimistic and pessimistic sides when all the facts (or all the facts we're ever going to get) are in. Some materials have been recovered after many days, weeks, or months under hostile control with no evidence that they knew or cared what they had. In other cases, post mortems have shown losses to have been significantly more substantial than were suggested by the early "facts."

~~(C)~~ Finally, we have found it prudent to treat damage assessments as exceptionally sensitive documents, for two reasons. The first is that they explain just what the materials are and how they could be exploited by a canny opponent. The second is that they reveal our own judgment on what was and wasn't lost. That information is important to any enemy, particularly if we were wrong, and he has been able to recover something we think he does not have.

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TRANSPOSITION SYSTEMS REVISITED

(C) In Volume I, it was noted that transposition systems were thrown out of our lexicon because they contained the seeds of their own destruction - all of the elements of plain language appear in the cipher text; they've merely been moved around with respect to one another. A jigsaw puzzle, in fact.

(C) Turns out, the same deficiency exists with equipments designed to destroy classified paper by shredding and chopping it into small pieces. The spectacle, in early 1980, of Iranian "students" occupying the US Embassy in Teheran, laboriously fitting together shredded materials comes to mind. In the destruction world, the problem was more or less solved by insisting that the pieces be so small and numerous that worlds of work would produce only fragmentary results.

(S) Our current standard - no destruction machine approved unless the resultant fragments were no larger than 1.2 mm x 13 mm (or 0.73 mm x 22.2 mm depending on the crosscut shredder used) was arrived at viscerally. But when the technology came along, we verified the standard by investigating the computer-assisted edge-matching or similar techniques which could see and remember shapes in a large display of small two-dimensional objects, and sort out those that fit together. As a result, we feel more comfortable about the question of whether such stuff can be reconstructed, however painstaking the attack. (As always, though, there are pressures to relax the standard, allow larger chunks because the finer the grain you demand, the more costly and time consuming the process. In a chopper, for example, you need more and finer blades, finer screens, and more cycling of the machine.) The material in Teheran by the way, was not from the crypto-center and was the product of a machine which we had specifically disapproved for our purposes.

(C) The transposition idea for cryptography did not stay dead with us. It had enormous attraction in the voice encryption business because if elements of speech could simply be arranged (transposed) in time and/or frequency, that would eliminate the need for digitization, which would in turn save bandwidth and still give good fidelity when it was unscrambled (untransposed). That meant enciphered voice of reasonable quality could be driven through narrowband transmission systems like ordinary telephone circuits and HF radio. Long-haul voice communications would be possible without large, complex very expensive terminals to digitize and still get the fidelity required.

(S) So, PARKHILL. Instead of making our fragments physically small as in a paper destructor, we made them small in time - presenting a brand new jigsaw puzzle each 1/10th of a second. Solvable? Sure. All you have to do is reconstruct 600 completely separate and quite difficult cryptograms for each minute of speech. We calculate that a good analyst might do a few seconds worth a day. Looks to be a risk worth taking - with that plain language alternative staring us in the face. We did, however, impose some limits in its use.

(S) We had never before fielded a less than fully secure crypto-equipment and, as our various caveats on its security limitations were promulgated, they sent some shock waves through the customer world and caused some internal stress in S. Our applications people quite rightly sought maximum use where plain language was the only alternative, while security analysts (also rightly) expressed continuing reservations on whether its usage could really be confined to tactical and perishable traffic - particularly as it gravitated increasingly towards wireline application rather than just HF radio for which it was originally designed.

(S) Part of the difficulty may have been that the only formal, objective crypto-security *standard* ever published in S is the High Grade Standard for equipments - systems meeting that standard are essentially approved for any type of traffic you might specify for their fifteen or twenty year life. No intermediate or "low-grade" standard has been adopted, despite yeoman efforts to devise one. Ironically, even among the high grade systems, there is considerable variation in their overall security potential - some provide

~~SECRET~~

kind of traffic they can process. At this writing, however, rumor has it that there is a sub-rosa paper authored by a fresh face entitled something like: "Manual systems - Are they Worth the Paper They're Printed On?" COMSEC will be well-served with critical re-examination of old ideas and quite a batch of hoary premises (including some in Volume II), particularly by our new people. Just be sure of your facts.



MORE MURPHY'S LAW

~~(S)~~ There have been occasions when we have had reason to suspect unauthorized access to various cryptomaterials which we could not prove. In these circumstances, if we can recover the material in question, we are likely to subject it to laboratory analysis to see if we can find evidence of tampering, unexplained fingerprints, and so on. One such case involved an operational T.S. key list being examined for latent prints in an S2 chemical lab. When the document was placed on a bench under the powerful blower system used to evacuate fumes at that position, this highly sensitive strictly accountable item was sucked up and disappeared into the elaborate duct-work system above the false ceiling.

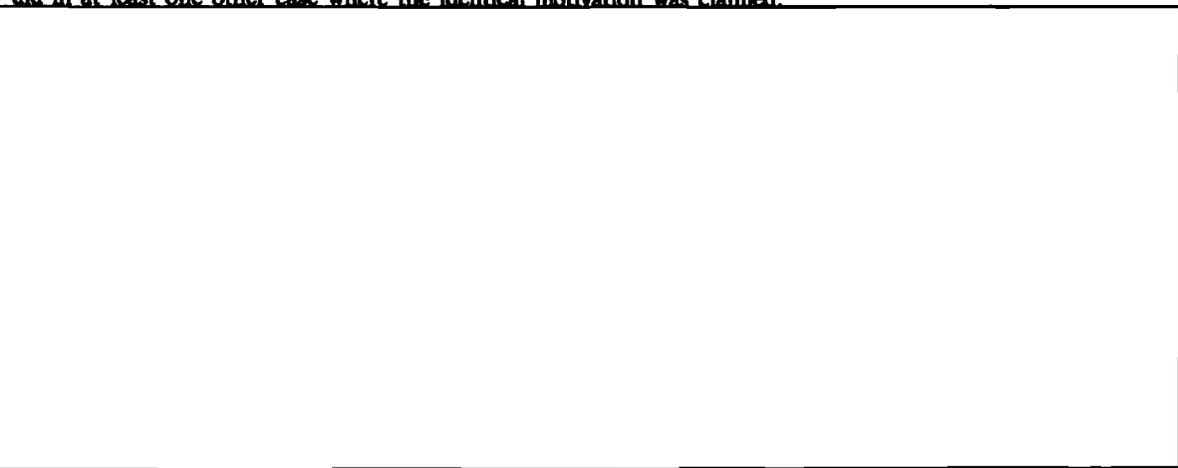
~~(C)~~ For NSA to have lost that keylist would have been a matter of acute embarrassment and there was, thus, considerable milling about. People were dispatched to the roof to check the vent with visions of our key list wafting somewhere about the wilds of Fort Meade. The vent was screened, however, and the document had not come up that far - it was somewhere in the bowels of the building in several hundred feet of ducting. GSA technicians arrived, and work was started from the bottom. At the first elbow, there was a small jam of paper, cotton, and cleaning rags, but no key list. About 20 feet along at another sharp bend, tin snips were used to open up the duct, and there was the document, snagged on some jagged protuberance. A relieved custodian clutched the document, and no compromise was declared.

~~(C)~~ An automobile crashed in Texas and the trunk sprang open. State troopers found a suspicious-looking duffle bag and checked its contents. Hundreds of low-level Op-Codes and authenticators were inside. The driver claimed not to have known the material was there; the car belonged to his brother-in-law, a Sergeant who had been shipped to Vietnam a few months earlier. He was tracked down and, sure enough, had left the material in the trunk for the duration. He had evidently been on a run to the incinerator with a burnbag full of used materials, had run out of time, and shipped out leaving the chore undone. He claimed he intended to get rid of the stuff when he got back.

~~(S)~~ Somebody moved into a small apartment near a Navy base in California. Far back on a top closet shelf he found a clip-board. On the board were two T.S. ADONIS keylists and several classified messages. The previous resident, a military man, had occupied the apartment only briefly, and swore he had never seen the material in his life. The origin of the keying material was traceable by short title, edition, and *register number*, and turned out to have been issued to a unit at Camp Lejeune.

~~(S)~~ More research showed that a Marine Sgt who had had access to the material had been sent to the West Coast, and sure enough, had lived for a while in the apartment where the documents were found. He was located and admitted that he had squirreled the material away, and claimed he had then forgotten it. His motive? Simply that classified documents "fascinated" him.

~~(C)~~ Strangely enough, this is a recurring theme. In this case, the polygraph seemed to bear him out, as it did in at least one other case where the identical motivation was claimed.



jettison as a way to get rid of our stuff unless at very great depths and in completely secret locations. (Shortly after WWII, small Army training crypto-devices called the SIGFOY were disposed of beyond the 100 fathom curve off Norfolk. Some years later, they became prize souvenirs for beach combers as they began washing ashore.)

~~(C)~~ **UNSOLVED PUZZLE** - We used to store a lot of cryptomaterial in a warehouse at Ft. Holabird. It was fenced and protected by a 24-hour armed civilian guard. One evening, such a guard saw an individual inside the fence, evidently attempting to penetrate the warehouse. He drew his weapon, cried "Halt!" and led the individual to the guard shack and started to call in for help. About that time, the intruder started running, climbed the fence, and disappeared. We asked the guard why he didn't shoot - he said he was afraid he might hurt somebody. It was one of the few attempted penetrations we know of, and has never been resolved.

~~(C)~~ **CONFETTI** - When we manufacture one-time tape, a by-product of the punching process is millions upon millions of tiny, perfectly circular pieces of paper called "chad" that come out of holes in the tape. This chad was collected in burn bags and disposed of. Someone thought it would make good public relations to give this stuff to high school kids for use as confetti at football games. Inevitably, one of the burn bags was not quite empty when the chad went in. At the bottom, were a couple of TOP SECRET key card book covers and a few assorted keys. They carried the impressive caveats of those days like "CRYPTO - CRYPTO-CLEARANCE REQUIRED" and were, to use a term earlier referred to, "fascinating" to the kids when they discovered them.

~~(C)~~ One of the girls, whose father happened to be an Army officer, tacked some of this material on her souvenir board. When Daddy saw it, he spiralled upward. He decided that it must be destroyed immediately; but first made a photograph of it for the record. He tore it up, flushed it away, and reported in. With some difficulty, various cheerleaders and other students who had glommed on to some of this material were tracked down, and persuaded to part with it. We no longer issue confetti.

~~(C)~~ We used to keep careful records of security violations in S, publicize them, and run little contests to see what organization could go longest without one. A retired Lt. Colonel wrecked SI's outstanding record as follows:

~~(C)~~ He reported to work one morning and found one of those ominous little slips on his desk, asserting that a paper under his blotter carried a safe combination, and "requesting" him to report to Security at once. He was outraged - he had never been guilty of a security violation in his life; the safe combination was not his, nor did it match any safe in his office. He rushed out the door and down to the Security Office. They accepted his story, cancelled the "violation," and he returned to his office somewhat mollified.

(U) There, on his desk, was another violation slip. He had left his office door open when he reported to security, and that was against the rules. That one stuck.

~~(C)~~ ~~(A)~~ (now) very senior official in S bent the rules by starting out to a conference in the Pentagon with some classified papers but without escort. He got as far as Foxhall Road in an ice-storm where he was confronted with a pile-up of cars that had skidded uncontrollably down into the hollow adjacent to the Girls' School there. He managed to slide to a stop without adding to the pile, got out, and immediately found himself in the path of a following car skidding toward him. To see him now, you would not believe that he made the only route to safety - over the seven foot chain link barbwire-topped fence around the school. He got some lacerations in the process, however, and someone took him to Georgetown Hospital for treatment. He refused to go, however, until he was able to flag down an NSA employee (our Adjutant General at the time!) to take custody of his classified materials.

~~(C)~~ There have been, by the way, rather serious incidents involving classified materials in automobiles. In one case, an individual carefully locked a briefcase full of classified reports in the trunk of his car while he made a quick stop at a business establishment. The car was stolen while he was inside. So, watch it.

~~(C)~~ When technical security teams "sweep" our premises, one of their chores is to examine conduits for extraneous wires, trace them out, or remove them. We had a peculiar case at Nebraska Avenue (the Naval Security Station at Ward Circle where various parts of the Agency were tenants from 1950 until 1968). An inspector on the third floor removed a floor access plate to examine the telephone wiring and saw a wire begin to move. He grabbed it, retrieved a few feet, then unknown forces on the other end began hauling it back. A tug of war ensued. Turned out that a fellow-inspector on the floor below was on the other end.

CLASSIFIED TRASH

~~(C)~~ One day, back in the '60's, one of our people was poking about in the residue beside the Arlington Hall incinerator. The incinerator had been a headache for years: the screen at the top of the stack had a habit of burning through and then it would spew partially burned classified COMSEC and SIGINT materials round and about the Post and surrounding neighborhood. Troops would then engage in a giant game of fifty-two pickup. This day, however, the problem was different - the grate at the floor of the incinerator had burnt out and the partially burned material, some the size of the palm of your hand, was intermixed with the ash and slag.

~~(C)~~ There was no way of telling how long the condition had persisted before discovery, so we thought we had better trace the ash to the disposal site to see what else was to be found. The procedure was to wet down the residue for compaction, load it on a dump truck, and haul it away. In the old days it had evidently been dumped by contractors in abandoned clay pits somewhere in Fairfax County (and we never found them); but the then current practice was to dump it in a large open area on Ft Meyer, South Post, adjacent to Washington Boulevard.

~~(C)~~ Our investigator found that site, alright, and there discovered two mounds of soggy ash and assorted debris each averaging five feet in height, eight to ten feet wide, and extending over 100 yards in length. He poked at random with a sharp stick, and thought disconsolately of our shredding standards. Legible material was everywhere - fragments of superseded codes and keying material, intriguing bits of computer tabulations; whole code words and tiny pieces of text. Most were thumb-size or smaller; but a few were much larger. Other pokers joined him and confirmed that the entire deposit was riddled with the stuff. Some of it had been picked out by the wind and was lodged along the length of the anchor fence separating the Post from the boulevard.

(U) Our begrimed action officer was directed to get rid of it. *All* of it. Being a genius, he did, and at nominal cost. How did he do it?

~~(S)~~ The solution to this problem was most ingenious - a truly admirable example of how a special talent combined with a most fortuitous circumstance eventually allowed us to get all that stuff disposed of. I won't tell you the answer outright: instead, I will try to aggravate you with a very simple problem in analysis of an innocent text system. Innocent text systems are used to send concealed messages in some ordinary literature or correspondence. By about this time, you may suspect that perhaps I have written a secret message here by way of example. That, right, I have! What's here, in fact, is a hidden message which gives you the explanation of the solution we accepted for disposing of that batch of residue. If we ever have to do it that way again, it will be much more difficult for us because the cost of everything has escalated, and I doubt we could afford the particular approach we took that time.

~~(S)~~ If you are really interested in how innocent text systems are constructed, he advised that there are twenty-jillion ways to do it - every one of them different. Some of them may use squares or matrices containing an encoded text with their values represented by the coordinates of each letter. Then those coordinates are buried in the text. About another million ways - a myriad - are available for that last step. In fact, the security of these systems stems mostly from the large variety of methods that can be used and on keeping the method (the logic) secret in each case. Once you know the rules, solution is easy. So now, find my answer above - no clues, except that it's very simple, and one error has been deliberately incorporated, because that is par for the course.

UNCLASSIFIED

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